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# HUMAN FACTOR EVALUATION OF THE USMC M1955 ARMORED VEST AND THE PROPOSED TITANIUM NYLON IMPROVED CONVENTIONAL MUNITIONS PROTECTIVE ARMORED VEST (48 PLATE)

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Aberdeen Proving Ground, Maryland

March 1973

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## HUMAN ENGINEERING LABORATORY

### ABERDEEN PROVING GROUND, MARYLAND

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13. ABSTRACT


A human factors evaluation of the Army Simplified 48-Plate Titanium/Nylon Armored Vest and the M1955 USMC Doron Armored Vest was conducted by the U. S. Army Human Engineering Laboratory. The vests were compared as to physical characteristics, anthropometric measurements, vest movement and static exercise, employment of small arms by troops equipped with the vests, and user acceptance. The results yielded many points of contrast between vests, but no overriding superiority of either vest was noted. Recommendations are made to improve the qualities of the Simplified 48-Plate Titanium/Nylon configuration, based on the conclusion that a greater potential for further development is seen in the articulated configuration.


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### OBJECTIVE

The objective of this research by the Human Engineering Laboratory (HEL) was to compare (from a human factors point of view) the Simplified Titanium Nylon Improved Conventional Munitions (ICM) Protective Armored Vest (48 plate) to the USMC M1955 Armored Vest in a manner which would pinpoint the best features of the two vests.

### DISCUSSION

a. The Simplified Titanium Nylon (STN) Armored Vest is constructed with articulated pivot shoulder pads (open-shoulder design) and a fitted waist. The USMC M1955 Armored Vest (USMC) is a closed-shoulder design (tight fitting neck and arm opening) with a loose fitting waist. The STN provides full torso and pectorial ICM protection. ICM protection of the USMC vest stops just below the pectorial girdle with conventional ballistic protection around the shoulder area. The STN is approximately 2.5 pounds lighter than the USMC vest. The STN employs titanium plates while the USMC vest uses Doron reinforced plastic resin as the main ballistic material.

Because of the similar ballistic characteristics and dissimilar design characteristics, a comparison of the two vests offered an opportunity to learn which design characteristics are most desirable in ICM protective vest. Furthermore, since the STN is still in development, this comparison offered an opportunity to provide human design inputs to its development. The comparison also allowed HEL to evaluate test procedures which have evolved under the Five-Year Technical Plan for Personnel Armor Systems.

b. The vests were compared by means of five procedures: (1) the vests were classified as to design characteristics, dimensions and weight; (2) anthropometric measurements were taken of men with and without the vests and with load-bearing equipment worn over the vests; (3) measurements were made which show vest-movement characteristics on the body of the wearer and silhouette characteristics of the wearer, with and without the vest. (Additionally, men wearing vest with and without load-bearing equipment participated in exercises designed to simulate typical movements made in a tactical situation); (4) rifle-firing behavior was examined with the vests plus load-bearing equipment; and (5) user acceptance was estimated from the comments of a consumer panel.

### FINDINGS

Several findings tend to complement each other:

1. Design characteristics, dimensions and weight classification show that while both vests are produced in three sizes, neither vest has sized vest length or arm openings.

2. Anthropometric measurements show that vests cause dramatic increases in the dimensions of men wearing them, a finding of considerable importance in the design of troop seats, portals and perhaps even field fortifications.

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3. The vest-movement characteristics of both vests reduce the total ballistic coverage afforded the individual in certain postures. The STN is significantly better than the USMC vest in this regard. The silhouette of the wearer is increased in both vests; however, the USMC vest has a slightly lower silhouette than the STN. Exercises show that both vests restrict the individual and cause discomfort. The point of discomfort for the two vests are considerably different (shoulder and stomach for the STN, neck and underarms for the USMC.

4. During rifle firing, troops wearing the STN were able to slew to the target faster than troops wearing the USMC vest; however, accuracy of firing was equal. Motion pictures show that in prone position the shoulder area of the STN bunches. This effect is responsible for the increased silhouette mentioned earlier and probably reduces ballistic protection across the top of the shoulders.

5. The consumer panel found the STN to be superior to the USMC vest. Nevertheless, several problems regarding the STN were highlighted by the group; the most frequent complaints were that the shoulder pads of the STN vest cause binding and discomfort along the sides of the neck and that the stomach area of the vest binds at the groin.

## CONCLUSIONS

a. Present vests usually come in three sizes; however, measurements show the length and arm opening of neither vest are sized. Sizing criteria for these dimensions should be considered.

b. Anthropometric measurements show considerable increase in the girth of men wearing armor and load-bearing equipment. In many cases, waist circumference doubles when equipment is worn.

c. While both vests exhibit movement about the torso of the wearer, the STN moves less than the USMC vest. The silhouette of the USMC vest is slightly better than the STN, but the STN can easily be improved in this regard. Exercises show that the STN shoulder-pad assembly and front length cause the most discomfort and restriction. Problems with the USMC (arms and neck) can be associated with the closed-shoulder design of the vest.

d. The shoulder bunching of the STN occurs as a result of the solid-elastic side-closure system which inhibits front/rear shearing of the vest.

e. The user accepts the STN as the better overall vest, but with qualification. The STN shoulder area must be improved and the stomach area must also be redesigned.

f. The findings of this evaluation indicate the open-shoulder/fitted waist design is superior to the closed-shoulder/loose waist as far as rigid articulated body armor is concerned.

## RECOMMENDATIONS

The STN vest should be modified to improve the areas cited in the investigation. The basic design of the USMC vest severely restricts modifications, since the vest achieves most of its stability from the close-fitting neck and arm openings. Increasing these openings without fitting the waist will only accentuate the already unfavorable movement characteristic of the vest.

The STN should be modified as follows:

a. Extend the arm scye (underarm) area opening by one inch. Future research should concentrate on arm-opening sizing criteria.

b. Shorten the length or rearticulate the lower front of the STN. Future research should provide front-length sizing criteria.

c. Increased articulation of the shoulder-pad assembly should further improve vest-movement characteristics. Additionally, providing the option of passing load-bearing equipment suspenders under the shoulder pad assembly should provide better shoulder articulation.

d. Shoulder bunching can be contained by providing elastic-drawstring side closures instead of solid-elastic side closures.

# HUMAN FACTOR EVALUATION OF THE USMC M1955 ARMORED VEST AND THE PROPOSED TITANIUM NYLON IMPROVED CONVENTIONAL MUNITIONS PROTECTIVE ARMORED VEST (48 PLATE)

## INTRODUCTION

This report deals with the results of a series of experiments designed to isolate the most advantageous features of the Simplified Titanium/Nylon 48-Plate Improved Conventional Munitions Protective Armored Vest (STN) and the USMC M1955 Doron Fragmentation Protective Armored Vest (USMC). These two vests were selected because they both provide the soldier with Improved Conventional Munitions (ICM) ballistic protection. Further, the basic designs of the two vests differ considerably. Because of these differences, a comparison between vests offered an opportunity to evaluate the methods used by the U. S. Army Human Engineering Laboratory (HEL) to compare candidate armored vests.

To compare the STN and USMC vests, five procedures were used. The first procedure was classification of design characteristics, weight and dimensions of the vests. The second involved detailed anthropometric measurements of test subjects with and without combat ensembles including vests. The third procedure included measuring vest-movement characteristics, silhouette measurements and collecting subjective measures of comfort, binding and restrictions during exercises designed to simulate body movements soldiers would use in the field (8). Rifle firing by troops equipped with the two vests was evaluated using hit/miss, time to fire and photographic data during the fourth procedure (1). Finally, user acceptance of the two vests was considered (5).

Twenty-two infantry soldiers (MOS 11 BX and 11 CX) served as subjects. The average age of the group was 25.4 years (minimum 19 years, maximum 43 years) and the average rank was E-5 (minimum E3, maximum E6). Nineteen of the 22 men had served in Southeast Asia as infantrymen.

Subject selection was based on availability, medical restrictions (i.e., no physical profiles) and MOS. Since random sampling was impossible, certain measures of the group were submitted to analysis to determine if the group was representative of the Army population.

Table 1 shows the results of F tests and t tests for the sample compared to U. S. Army Infantry and USMC anthropometric data (2). These analyses were conducted on four measures: stature, weight, chest circumference and waist circumference. It is important to note that the F and t tests show that the sample used in this evaluation represents a group of men who are larger than the average soldier or Marine. Further, the sample does not represent the entire distribution of body sizes found in the U. S. Army or USMC troops.

To further describe the relationship of the sample to U. S. Army Infantry and USMC troops, the data were organized to present the mean dimensions of individuals wearing a particular vest size. Table 2 shows this relationship. Of the 19 men measured, three wore the STN size small, 12 the STN medium, and four the STN large. Data for the same men fitted with USMC vest shows 13 wore the USMC regular, four wore the USMC large, and two wore the USMC extra-large size. These findings indicate that the medium sizes for both vests were tested over a wider range of body types than the more extreme sizes.

## TABLE 1

*Test for Significance*
Results of Sample Distribution Analysis

| | $\bar{X}$ | SD | Range | Min. | Max. | n | t | Sig. | F |
|---|---|---|---|---|---|---|---|---|---|
| Weight | | | | | | | | | |
| Sample | 180.63 | 38.81 | 148 | 129 | 277 | 19 | | | |
| US Army Infantry | 160.34 | 22.81 | 172 | 100 | 272 | 3425 | 2.2797 | .01 | 3.89* |
| USMC | 160.16 | 19.67 | 138 | 110 | 248 | 2006 | [illegible] | .01 | 3.89* |
| Stature | | | | | | | | | |
| Sample | 69.68 | 2.93 | 10.25 | 65.75 | 76.0 | 19 | | | |
| US Army Infantry | 68.64 | 2.61 | 15.4 | 61.0 | 76.4 | 3429 | 2.63 | NS | 1.39NS |
| USMC | 68.72 | 2.48 | 15.7 | 61.7 | 79.4 | 2008 | 1.43 | NS | 1.39NS |
| Chest Circumference | | | | | | | | | |
| Sample | 39.50 | 4.24 | 15.25 | 33.0 | 48.25 | 19 | | | |
| US Army Infantry | 37.01 | 2.60 | 18.9 | 30.00 | 48.9 | 3429 | 2.46 | .01 | 3.39* |
| USMC | 37.11 | 2.30 | 17.7 | 31.6 | 49.3 | 2008 | 2.52 | .01 | 3.39* |
| Waist Circumference | | | | | | | | | |
| Sample | 35.21 | 5.79 | 24.00 | 28.5 | 52.5 | 19 | | | 13.46* |
| US Army Infantry | 31.62 | 3.12 | 24.2 | 23.8 | 48.00 | 3429 | 2.03 | .01 | |
| USMC | 31.22 | 2.49 | 21.3 | 24.9 | 45.8 | 2008 | 2.26 | .01 | |

$\bar{X}$ age = 25.64
Range = 19-43

*p < .01

## TABLE 2

Sample by Vest Size Analysis

| | | | Weight | Stature | Chest | Waist |
|---|---|---|---|---|---|---|
| STN | Small | n = 3 | 134.5 | 69.5 | 33.25 | 28.5 |
| | Percentile | | 12.5 | 62 | 7.0 | 15. |
| | Medium | n = 12 | 173.35 | 69.35 | 39.02 | 34.39 |
| | Percentile | | 76 | 60 | 82 | 82 |
| | Large | n = 4 | 237.25 | 70.81 | 45.50 | 43.62 |
| | Percentile | | over 99 | 80 | over 99 | over 99 |
| USMC | Medium | n = 13 | 163.76 | 69.65 | 37.54 | 32.5 |
| | Percentile | | 62 | 59 | 63 | 68 |
| | Large | n = 4 | 200.43 | 70.06 | 41.37 | 37.56 |
| | Percentile | | 95 | 70 | 94 | 95 |
| | Extra-Large | n = 2 | 251.25 | 69.12 | 48.25 | 48.25 |
| | Percentile | | over 99 | 59 | over 99 | over 99 |

## CLASSIFICATION

Much can be learned about the two vests by listing physical characteristics (Table 3).

Some generalities about the two vests are evident from Table 3. The USMC vest is manufactured with small neck and arm openings, while the STN has somewhat larger neck and arm openings. The USMC vest is loosely fitted at the waist. The STN is fitted closer at the waist. The front length of both vests is the same, while the STN vest is 2.25 inches longer in the rear. The shoulder bulk of the USMC vest is slightly less than that of the STN, while the chest and back bulk of the two vests is equal. The USMC vest is approximately 2.5 pounds heavier than the STN vest. The two vests are shown in Figure 1.

### USMC Armored Vest[1] - M1955

The USMC Doron vest is of the closed-shoulder design (Fig. 1). The shoulder area, upper chest and upper back are protected by 12-ply ballistic nylon. A ballistic collar, 3/4 inch high in the rear, tapers to the front of the neck opening.

The USMC Doron vest is named for the Doron resin-reinforced fiberglass plates which comprise the main ballistic protection of the device. Twenty-three plates are used in the regular size vest. Nineteen plates are contained by cloth pockets in two concentric rings around the midriff of the vest. Two plates are located across the rear of the vest along a line at a level with the arm opening. The remaining two plates are located over the heart/lung region of the wearer in the front of the vest. (Large and X-Large sizes have 25 and 27 plates, respectively.) The plates are 5.25 inches square, approximately 1/8 inch thick, rigid and slightly curved to conform with the body. The corners of the plates are rounded and the plates overlap to provide thorough protection.

The vest is closed by a zipper coupled with four snaps located at the midline, down the front of the vest. Three pockets are located on the front of the vest. Two of these are provided with flaps secured by buttons. The third pocket is small and has no flap. The vest is provided with a web cord at the right shoulder to assist in rifle firing. A web strip with eyelets is provided at the waist so that equipment can be carried on the vest.

The vest has been used by Marine Combat Troops throughout the Viet Nam conflict with reportedly good ballistic protection to the user.

[1]The USMC M1955 Doron Vest was developed by an interservice board (3).

TABLE 3

Physical Characteristics of USMC and STN Vest Configurations

| | USMC | | | STN | | |
|---|---|---|---|---|---|---|
| | Med | Lg | XL | S | Med | Lg |
| 1. Neck Opn. Circumference | 16.5" | 18.5" | 21.0" | 21.0" | 23.0" | 24.0" |
| 2. Arm Opn. Circumference | 23.5" | 23.5" | 23.5" | 25.0" | 25.0" | 25.0" |
| 3. Chest In. Circumference | 42.25" | 46.50" | 48.50" | 40.00" | 42.50" | 47.00" |
| 4. Waist In. Circumference | 43.25" | 49.00" | 52.50" | 41.50" | 43.00" | 45.0" |
| 5. Front In. Length | 17.00" | 17.00" | 17.00" | 17.00" | 17.00" | 17.00" |
| 6. Back In. Length | 19.75" | 19.75" | 19.75" | 22.00" | 22.00" | 22.00" |
| 7. Bulk @ Shoulder | .9cm | .9cm | .9cm | 1.2cm | 1.2cm | 1.2cm |
| 8. Bulk @ Chest | .4cm | .4cm | .4cm | .4cm | .4cm | .4cm |
| 9. Bulk @ Back | .4cm | .4cm | .4cm | .4cm | .4cm | .4cm |
| 10. Weight in Pounds | 10.6 | 11.6 | 12.4 | 8.0 | 9.0 | 9.6 |
| 11. Federal Stock Number | 8470-576-4194 | 8470-576-4195 | 8470-576-4193 | NA | NA | NA |

F:g. 1. STN AND USMC ARMORED VESTS

## STN 48-Plate Armored Vest[2]

The Simplified 48-Plate Titanium/Nylon vest is a composite armor vest consisting of a ballistic collar, filler of water-repellant, 14-ounce, ballistic nylon and titanium plates contained by a ballistic shell (cover), and shoulder pads, all constructed in an articulated design. The collar consists of six layers of ballistic nylon covered with a layer of lighter-weight nylon cloth. The collar height is approximately 2¼ inches, and can be worn in either the up or down position.

The ballistic filler consists of two plys of 14-ounce water-repellent ballistic nylon. Forty-two curved, overlapping metal plates, each with slots, are suspended from the outer ply of the filler by means of fabritape looped through each slot and stitched to the filler. The filler component is stitched to the covers around the entire periphery to prevent migration and bunching. Each plate has a rubber peripheral-noise attenuator which separates the plate from surrounding plates.

The ballistic cover forms the shell of the vest and is fabricated from the same ballistic nylon which provides an abrasion-resistant surface. The cover has rifle patches sewn to the front shoulder section and to the front shoulder portion of the shoulder pads. These patches are provided to assist in positioning shoulder-fired weapons when the vest is worn as an outer garment. Two nylon bellow-type pockets with flaps are sewn to the front of the vest cover and two grenade hangers are sewn to the cover, above the pockets.

Each of the open-shoulder assemblies is constructed of three plates attached to ballistic nylon with a foam cushion and covered with the same ballistic material as the vest cover. The shoulder pads are articulated by means of a hinge-type seam and elastic tapes.

The vest has a Velcro "touch and close" front closure and incorporates elastic webbing and restraining straps at the sides. Small eyelets are located at the bottom inside edge of the cover to facilitate moisture drainage. The vest is made in small, medium and large sizes.

## ANTHROPOMETRIC SURVEY

Various clothing and equipment items cause the soldier's basic dimensions to extend over an extremely wide range. To document the changes due to interacting components of battlefield clothing ensembles, we conducted an anthropometric survey.

The results of the survey show how the separate components interrelate and result in growth over the nude dimensions. These dimensional increases must be taken into account by equipment designers when establishing minimum clearances for seat widths, overhead clearance, escape hatch and door widths.

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[2] The STN was developed by U. S. Army Natick Laboratories under contract with IIT Research Institute. (Contract No. DAAG17-67-C-0079). The vest has never been procured or issued to combat troops in the field.

Nineteen of the subjects were measured in each of the following seven clothing conditions:

1. Cotton undershorts, a tee shirt and cushion-sole socks.

2. Added to the first condition, fatigue trousers and shirt, a web belt and combat boots.

3. All of the above, plus load-bearing equipment which included combat suspenders, pack with one C-ration unit, pistol belt, entrenching tool carrier, canteen with carrier/cover, two ammunition pouches with four M-16 rifle magazines each, and first-aid pouch.

4. All of the above, plus the 48-plate titanium vest.

5. All of the above, without load-bearing equipment.

6. Clothing items from one and two, plus the Marine Corps Doron vest.

7. Clothing items from one, two, three and six.

The top half of a Siber Hegner 2000mm anthropometer was used as a large sliding caliper when measuring body breadths and depths. These measurements were taken to the nearest millimeter. Body circumferences were measured with a fiber-glass-reinforced cloth measuring tape which was read to the nearest quarter-inch. The subjects' weights were measured on a calibrated Detecto Model 239 platform scale to the nearest quarter-pound. This scale has a vertical rod calibrated in inches and quarters and it was used to measure stature and standing eye height. For seated measurements a Navy Integrated Anthropometric Device (BUWEPS P/N 64A105H1-1) was used.

For measurement, the data for each type and size of vest are presented separately so that sizing system differences are readily apparent. The growth in each dimension due to clothing or equipment additions are also shown. The distribution of the 19 subjects across the range of vest sizes is shown in Table 4.

TABLE 4

Distribution of Subjects by Vest Size

| Type | Small | Medium | Large | Extra Large |
|---|---|---|---|---|
| Titanium | 3 | 12 | 4 | |
| Marine Corps | | 13 | 4 | 2 |

The results of the survey are presented in Tables 1A through 24A in the appendix.

## VEST-MOVEMENT CHARACTERISTICS

Nineteen enlisted men served as subjects for the comparison of vest-movement characteristics. The vests used were small, medium and large U. S. Army Simplified 48-Plate Titanium/Nylon Vests, and regular, large and extra-large USMC Doron Vests. An anthropometric measuring apparatus was used to make the comparison.

Following the anthropometric measurements described in the anthropometric section, subjects were required to assume three different postures so that further measurements could be made. The first posture was a standing position, arms extended to the sides. The second posture was also standing, arms over head. The third posture was a prone firing position. Primary interest was in the amount of vest movement associated with the particular posture. Movement was measured at a point mid-way along the stomach width dimension (front and back) and mid-way along the stomach depth dimension at the side, while the subject was in the arms-up and arms-out postures. In the prone firing posture, measurements were taken at the mid-line waist high and on either side. The resting position of the vest was noted in each case while the subject was in a standing position, arms to the sides. Movement was measured from this resting point. Each subject was measured in both vests with and without load-bearing equipment.

The data for arms-up and arms-out were reduced and analyzed, by analysis of variance. The results are presented in Table 5. As indicated, significant vest and position effects ($p < .05$, $F = 5.23$ df 1/90 and $p < .01$, $F = 2.24$ df 5/90) were evident. Further, the vest by position interaction was significant ($p < .01$, $F = 5.81$ 5/90).

The data for arms out, arms-up, and prone position for the entire sample were plotted to estimate the area exposed by ride-up. A first-order approximation was calculated for both vests in the three postures (Fig. 2). The data were also organized so as to represent the size of the vests worn by a given subject, because the sizing systems of the two vests are not similar. The area of exposure for the two vests for the prone position by vest size is listed in Table 6. Values are listed for vests with and without load-bearing equipment.

The findings indicate that the STN vest rides up less than the USMC vest. This finding has two implications. First, the STN evidently moves with the body of the wearer, while the USMC vest moves about the body of the wearer. The torso construction of the two vests is not similar. The USMC vest tends to be loose fitting at the waist and snug fitting at the shoulder. The STN is fitted at the waist and loose, as a result of the open-shoulder configuration, around the pectoral girdle. The suggestion is that the fitted waist/open-shoulder configuration found in the STN maintains position on the body better than the loose waist/closed-shoulder configuration of the USMC vest.

The second implication of these findings is related to ballistic protection. Naturally, as the vest rides up, some area of the body is exposed. Consulting Figure 2, it can be seen that in the prone position, an estimated 77.13 square inches of body surface is exposed for subjects equipped with the USMC vest, while 54.32 square inches are uncovered with the STN. It would seem that movement characteristics of the two vests appreciably affect the ballistic protection of the wearer. This finding alone creates a strong argument for the latter vest configuration (open-shoulder/fitted waist).

## TABLE 5

ANOVA Table for Vest Movement Data

| Source of Variation | SS | df | MS | F | p |
|---|---|---|---|---|---|
| A (Vests) | 37.37 | 1 | 37.37 | 5.23 | p .05 |
| B (Position) | 80.68 | 5 | | 2.24 | p .01 |
| C (Subjects) | 23.73 | 18 | 1.32 | | NS |
| AB | 244.00 | 5 | 48.80 | 5.81 | p .01 |
| BC | 42.00 | 90 | .47 | | NS |
| AC | 13.20 | 18 | .73 | | NS |
| Second Order Interaction | 758.00 | 90 | 8.4 | | |
| Total | 1199.00 | 227 | | | |

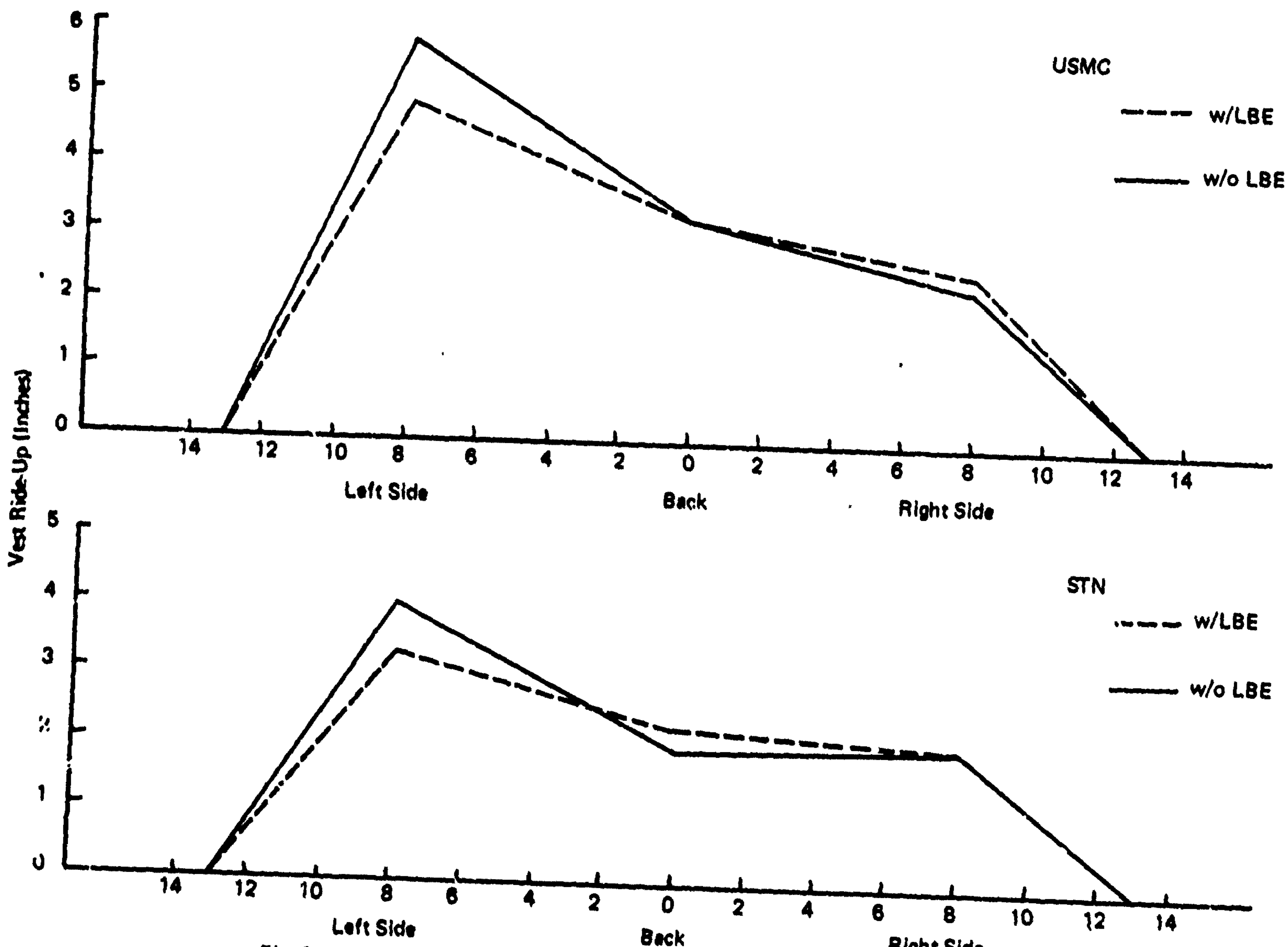


Fig. 2. FIRST-ORDER APPROXIMATIONS OF MEAN AREA COVERAGE LOST AS A RESULT OF VEST RIDE-UP

The movement characteristics of the two vests are important from yet another point of view. Since the USMC vest is not produced in a size small, subjects fitted with small STN vests were required to wear size regular USMC vests. The USMC regular vest weighs 10.6 pounds. The STN size small weighs 8.0 pounds or 19 percent less than the USMC vest. Looking at Table 6, we see a ride-up area for these men in the prone position of 62.25 square inches USMC and 40.77 square inches for the STN. This can be expressed as a 50 percent increase in movement between the two vests. In other words, these soldiers are carrying 2.6 pounds more armor for 21.48 square inches less coverage when wearing the USMC vest in certain postures. Adding weight while losing coverage is inefficient, and although this example is for small men, such inefficiency could cost an infantry company several hundred pounds in load-carrying capability. This inefficiency would be felt when the unit is being engaged by indirect fire (e.g., men in the prone position) which is precisely the time the armor is most needed by the troops. The findings presented in Table 5 are estimates of coverage loss. The Biostereometric Project (Ballistic Research Laboratory and Natick Laboratories) will accurately measure this phenomenon.

Further, findings indicate that when men stand with arms-up and arms-out, differences in the movement characteristics of either armor with and without load-bearing equipment are small (Fig. 2). A large between-vests difference is evident. There is considerable difference in movement characteristics of vests with and without load-bearing equipment in the prone position.

## SHOULDER SILHOUETTE

Subjects and apparatus for shoulder-silhouette measurements was the same as for the vest-movement measurements. While the individual was in the prone firing position a measurement was taken of the highest point of the shoulder area. This measurement was taken for both vests, with and without load-bearing equipment.

The data were reduced and analyzed by analysis of variance repeated measures (Table 7). The significant main effects are subjects (F · 5.28 df 18/72, $p > .01$) and load-bearing equipment ($F = 6.39$ df 1/36, $p > .05$). The vest x L. E. interaction was significant ($F = 23.29$ df 2/36, $p > .01$).

## TABLE 6

**Area Exposed by Vest Ride-Up for STN and USMC Vests With and Without Load-Bearing Equipment, Prone Position**

| Vest Size | | With LBE (Sq. Inches) | Without LBE (Sq. Inches) |
|---|---|---|---|
| Small STN | (8 lbs) | 40.77 | 41.36 |
| Regular USMC | (10.5 lbs) | 62.25 | 77.06 |
| Medium STN | (9 lbs) | 53.44 | 57.07 |
| Regular USMC | (10.5 lbs) | 65.49 | 72.26 |
| Large STN | (9.6 lbs) | 59.48 | 54.78 |
| Regular USMC | (10.5 lbs) | 85.96 | 101.91 |
| Large STN | (9.6 lbs) | 74.24 | 73.38 |
| Large USMC | (11.6 lbs) | 88.28 | 79.14 |
| Large STN | (9.6 lbs) | 64.80 | 73.78 |
| Extra Large USMC | (12.4 lbs) | 115.2 | 90.18 |

## TABLE 7

**ANOVA Table for Shoulder Silhouette Data**

| Source | SS | df | MS | F | p |
|---|---|---|---|---|---|
| $SS_{subjects}$ | 212.32 | 18 | 11.79 | 5.28 | .01 |
| $SS_{vests}$ | 6.50 | 2 | 3.25 | 1.45 | NS |
| $SS_{LBE}$ | 14.25 | 1 | 14.25 | 6.39 | .05 |
| Vest x LBE | 87.61 | 2 | 43.80 | 23.29 | .01 |
| Vest x Subjects | 92.86 | 36 | 2.58 | 1.37 | NS |
| LBE x Subjects | 19.44 | 18 | 1.08 | — | NS |
| Vests x Subjects x LBE | 68.00 | 36 | 1.88 | — | NS |
| Pooled Error | 160.88 | 72 | 2.23 | | |

Several findings resulted from the silhouette measurements. The interaction between vest and load-bearing equipment can be explained to some extent by information presented in the section on rifle firing. Briefly, it was found that the STN vest exhibited a characteristic bunching across the shoulders. This finding is discussed in detail under User Acceptance and Conclusions and Recommendations. The interaction can be attributed to shoulder bunching, which was observed in nine out of 10 men wearing the STN.

The mean profile height for subjects equipped with load-bearing equipment is 13.21 inches. This value decreased to 12.28 inches when load-bearing equipment is removed (a difference of .93 inches). This value represents the difference in shoulder profile which could be expected of soldiers in the prone fighting position with and without load-bearing equipment. If the same men were to throw off the load-bearing equipment, but retain either of the vests, their shoulder profile would decrease by approximately half an inch for STN and .17 inches for the USMC vest. However, if the vest was configured so that the individual could jettison both load-bearing equipment and vest, the shoulder profile would be decreased by 2.72 inches for the STN and by 2.23 inches for the USMC vest. Bearing in mind that neither of these vests are bullet-proof but are designed to provide fragment protection, it is easy to see that in combat the soldier may wish to rid himself of his gear to provide better mobility, better concealment or simply a smaller target for the enemy rifleman. In terms of area, the increased shoulder silhouette as seen from straight ahead of the shooter is estimated to be 52 square inches for the STN and 43.91 square inches for the USMC configuration. This area has no ballistic importance; however, from a systems's point of view, the size of the target area of a soldier is very important. Since the image presented to the eye decreases by half when the distance to the object doubles, at some point of range the increased target area would assist the enemy in target detection.

Further analysis of these results show that load-bearing equipment increases shoulder profile by approximately seven percent of the mean shoulder profile. The two vests cause approximately eight percent more increase or a total increase of approximately 15 percent. Finally, the STN and USMC vests with load-bearing equipment present an increase of 19 percent and 15 percent respectively.

This information supports an argument for incorporating load-carrying equipment into body armor. The USMC vest does have provision to carry some equipment attached to the web belt about the waist of the vest, but because of the loose-fitting waist, equipment carried there is unstable. These findings are based on standard load-bearing equipment worn over the vest.

## STATIC EXERCISE

Fifteen U. S. Army enlisted men served as subjects for the static exercise. They wore small, medium and large sizes of the STN armored vests and regular, large and X-large sizes of the USMC Doron armored vests.

Subjects were tested in four conditions. Each wore both STN and USMC vests, with and without load-bearing equipment. The test protocol consisted of exercises suggested by (IITRI). The exercises were completed in standing, seated and crouching positions:

### Basic Position

The test subject stands erect with his feet together and his arms hang relaxed at his sides.

### Position I

Subject stands erect, feet together, arms extended out horizontally from the sides of the torso with the palms of the hands facing the floor. Thus, a single straight line will connect the fingertips of the right and left hands.

### Position II

Subject stands erect, feet together, with arms crossed horizontally in front of body.

### Position III

Subject stands erect, feet together, arms extend horizontally backwards to the limit of their movement in this direction. The position is attained by swinging the arms in a horizontal plane (at the shoulder level) as though attempting to make the hands meet behind the body.

### Position IV

Subject stands erect, feet together, arms raised vertically upwards, with the palms of the hands facing each other and in contact.

### Position V

Subject stands with feet together and knees locked in a straight, vertical position. The thoracic cage is flexed forward by pivoting about the hip joint and bending the lumbo-sacral spine. Arms are extended out to the sides as in Position I.

### Position VI

Subject stands with feet together and knees locked in a straight, vertical position. The thoracic cage is flexed backward by pivoting about the hip joint and bending the lumbo-sacral spine. Arms are extended out to the sides as in Position I.

Position VII

Subject stands with feet together and knees locked in a straight, vertical position. The thoracic cage is flexed to the side by bending the lumbo-sacral spine and arms are extended out to the sides as in Position I.

Position VIII

Subject stands with feet together and knees and hips locked in a straight, vertical position. The thoracic cage is rotated (about the vertical axis of the body) to the side by rotating the lumbo-sacral spine. Arms are extended out to the side as in Position I.

Subjects performed the exercises and reported any binding or restricted movement they felt resulted from the body armor. Their comments were recorded in brief with emphasis on both body area and/or aspect of the vest involved in the reported interaction. Only subjects who could be properly fitted in both vests were used in this exercise.

Binding and restriction were reported in nine definable phrases. These terms were used by subjects and not dictated by the experimenter. Only those responses which were recorded for at least five of the 15 subjects are presented in Tables 8, 9, 10 and 11. Table 12 through 15 present the total number of reported interactions for each condition.

During the static exercises the following problem areas were identified.

STN Vest

Shoulder-Neck Interaction

When the subject raises his arms overhead, or crosses the extended arms in front of the torso, the articulated shoulder plate (Fig. 3) drives into the collar, causing binding along the sides of the neck area. This effect is more pronounced when load-carrying gear is worn. Further, the effect is most evident in the seated and crouching positions.

Stomach-Plate Lock

When the subject bends at the waist in the standing, seated and crouching positions, the stomach plates evidently lock, causing binding about the waist.

Axillary Binding

When the individual reaches from side to side in the standing, seated or crouching position, the thick seam under the arm causes binding.

USMC Doron Vest

Shoulder-Neck (Fig. 4)

When the subject raises his arms overhead, or crosses them in front of the torso, the nylon material bunches at the top of the shoulder. This bunching occurs because the vest tends to ride up and thus cause the collar to bind at the front of the neck.

## TABLE 8

Exercise Interactions, Subjects Equipped With STN
Without LBE

| | Standing | Sitting | Crouching |
|---|---|---|---|
| Bend Forward | lower plates stomach bind 8/15 | lower plates stomach bind 10/15 | lower plates stomach bind 10/15 |
| Bend Rear | | | |
| Bend Sides | | | |
| Rotate | | lower plates stomach bind 6/15 | |
| Front Cross | shoulder epaulet as sy. top of shoulders and sides of neck 6/15 | same as standing 10/15 | same as standing 10/15 |
| Overhead | same as above front of neck collar assembly | same as standing 9/15 5/15 | |
| Sides | | | |
| Backwards | | | |

TABLE 9

Exercise Interactions, Subjects Equipped With STN
With LBE

| | Standing | Sitting | Crouching |
|---|---|---|---|
| Bend Forward | | stomach bind 6/15<br>lower plates | |
| Bend Rear | | | |
| Bend Sides | underarms 5/15<br>heavy seam | same as standing 7/15 | same as standing 7/15 |
| Rotate | | | underarms 5/15<br>heavy seam |
| Front Cross | shoulder epaulet 6/15<br>assy.<br>top of shoulder | shoulder epaulet 9/15<br>assy.<br>shoulders and neck | same as sitting 8/15 |
| Overhead | shoulder epaulet assy.<br>and collar assy. 8/15<br>top of shoulder 6/15<br>+ shoulders and neck | same as standing 8/15<br>6/15 | same as sitting 5/15<br>and standing |
| Sides | | | |
| Backwards | top of shoulders 6/15 | same as standing 5/16 | |

## TABLE 10

Exercise Interactions, Subjects Equipped With USMC Armored Vest Without LBE

| | Standing | | Sitting | | Crouching | |
|---|---|---|---|---|---|---|
| Bend Forward | | | front of neck | 8/15 | same as sitting | 7/15 |
| Bend Rear | | | | | | |
| Bend Sides | | | front of neck | 7/15 | | |
| Rotate | | | front of neck | 5/15 | same as sitting | 8/15 |
| Front Cross | underarms seams | 8/15 | same as standing | 6/15 | same as standing and sitting | 7/15 |
| Overhead | front of neck collar assembly | 6/15 | top of shoulder<br>front of neck | 5/15<br>5/15 | front of neck | 5/15 |
| Sides | | | | | | |
| Backwards | front of neck collar assembly | | front of neck | 6/15 | front of neck | 5/15 |

TABLE 11

Exercise Interactions, Subjects Equipped With
USMC Armored Vest Without LBE

| | Standing | | Sitting | | Crouching | |
|---|---|---|---|---|---|---|
| Bend Forward | collar assy. front of neck | 5/15 | same as standing | 8/15 | same as standing and sitting | 6/15 |
| Bend Rear | | | | | | |
| Bend Sides | | | | | armpits | 5/15 |
| Rotate | | | | | front of neck | 5/15 |
| Front Cross | armpits top of shoulders | 6/15 | top of shoulders | 6/15 | same as sitting | 5/15 |
| Overhead | top of shoulders | 9/15 | shoulders and neck and front of neck | 7/15 5/15 | same as sitting | 6/15 |
| Sides | | | | | | |
| Backwards | | | front of neck collar assy. | 6/15 | | |

TABLE 12

Overall Interaction Reports STN With LBE

| | Standing | Sitting | Crouching |
|---|---|---|---|
| Bend Forward | 8 | 14 | 8 |
| Bend Rear | 1 | | 1 |
| Bend Sides | 6 | 10 | 7 |
| Rotate | 6 | 13 | 9 |
| | 21 | 37 | 25 |
| Front Cross | 15 | 14 | 11 |
| Overhead | 15 | 15 | 11 |
| Sides | 7 | 7 | 4 |
| Backwards | 10 | 8 | 6 |
| | 47 | 44 | 32 |
| | 68 | 81 | 57 |

TABLE 13

Overall Interaction Reports STN Without LBE

| | Standing | Sitting | Crouching |
|---|---|---|---|
| Bend Forward | 9 | 15 | 11 |
| Bend Rear | | | |
| Bend Sides | 2 | 5 | 6 |
| Rotate | 4 | 13 | 10 |
| | 15 | 33 | 27 |
| Front Cross | 10 | 14 | 13 |
| Overhead | 15 | 15 | 15 |
| Sides | 7 | 6 | 5 |
| Backwards | 5 | 4 | 4 |
| | 37 | 39 | 37 |
| | 52 | 72 | 64 |

TABLE 14

Overall Interaction Reports USMC With LBE

| | Standing | Sitting | Crouching |
|---|---|---|---|
| Bend Forward | 10 | 14 | 13 |
| Bend Rear | 2 | 3 | 4 |
| Bend Sides | 4 | 10 | 9 |
| Rotate | 5 | 14 | 12 |
| | 21 | 41 | 38 |
| Front Cross | 13 | 14 | 13 |
| Overhead | 13 | 15 | 14 |
| Sides | 10 | 10 | 6 |
| Backwards | 8 | 10 | 8 |
| | 44 | 49 | 41 |
| | 65 | 90 | 78 |

TABLE 15

Overall Interaction Reports USMC Without LBE

| | Standing | Sitting | Crouching |
|---|---|---|---|
| Bend Forward | 7 | 14 | 13 |
| Bend Rear | 3 | 2 | 3 |
| Bend Sides | 3 | 9 | 7 |
| Rotate | 4 | 13 | 11 |
| | 17 | 38 | 34 |
| Front Cross | 13 | 13 | 14 |
| Overhead | 13 | 14 | 12 |
| Sides | 6 | 6 | 7 |
| Backwards | 6 | 7 | 9 |
| | 38 | 40 | 42 |
| | 55 | 78 | 76 |

Fig. 3. SHOULDER/NECK INTERACTION STN VEST

Fig. 4. SHOULDER/NECK INTERACTION USMC VEST

Neck

When the individual bends at the waist in the standing, sitting, or crouching position, the vest rides up and the collar binds at the front of the neck.

Tables 12 through 15 show the overall number of restrictions reported by subjects during the exercise. The only large difference between the two vests occurs in the crouching position. Evidently, the STN caused less overall restriction than the USMC vest. Observation of the tests indicates that most of this difference is attributable to the arrangement of the plates about the girth and also to the arm openings of the USMC vest.

Generally, there is an overall difference in the number of reports between load-carrying equipment/vest and vest/without load-carrying conditions. As noted in the discussion of ride-up, there is a good bit of movement for both vests. Because of this movement, it is logical to assume that most of the restrictions occur as a result of movement of the vest to a limiting position followed by the pressure of the body attempting to push through that limit.

Also, as noted in the ride-up discussion, the USMC vest seems to move with respect to the body while the STN moves with the body. However, there is little overall difference between vests during the exercises. The difference occurs between load-bearing and without load-bearing equipment. There are more restrictions when load-bearing gear is added. These restrictions indicate that the mobility characteristics of both vest designs are defeated by load-bearing equipment.

Of the two vests tested, the STN seems to offer the better option for eliminating those points which limit or inhibit movement. The most frequently reported restriction of the STN is associated with the shoulder-pad assembly. Previous observation indicates that the shoulder pad of the 135-plate nylon titanium vest (T61-4) presents none of the problems seen in the 48-plate version. Since these assemblies are interchangeable, the more highly-articulated device is preferable.

Further, since the STN seems more stable than the USMC configuration and since load-bearing equipment adds limits to both vests, it seems logical to incorporate a load-bearing capability into an articulated vest. This capability might take the form of built-in suspenders or of shoulder pads which allow suspenders to be passed under the shoulder-pad assembly.

## RIFLE FIRING

Rifle firing is a basic infantry skill. The soldier must be able to bring fire on the target effectively. To achieve effective fire, the soldier must be quick and accurate with his basic weapon, the M16 rifle.

The following procedure measures hit/miss and time-to-fire data for troops equipped with the USMC and STN armored vests. Photographic data provides a graphic record of the behavior of the troops during rifle firing in the standing and prone firing positions.

Twenty U. S. Army enlisted infantrymen served as subjects for the rifle-firing test. The subjects wore small, medium and large Simplified Titanium/Nylon Armored Vests (STN), and regular, large and extra-large USMC Doron Armored Vests, under the standard combat ensemble. They fired M16 rifles.

An automated pop-up firing range was instrumented to provide hit/miss and time-to-fire data (Fig. 5, 6).

On the first day of testing, a qualification trial was conducted to estimate the subjects' individual shooting ability. Using M16 rifles, they fired 40 rounds each at five foam-cored aluminum pop-up targets placed at 30 meters.

The targets were arranged in a $60^{\circ}$ arc. To provide a total presentation arc of $120^{\circ}$, subjects were oriented facing the extreme lefthand target for 20 shots and facing the extreme righthand target for 20 rounds. This arrangement allowed slew time (time required to orient to the target) to be included in the total time-to-fire measurement. To minimize the effects of target detection, subjects were told the presentation order of the individual targets.

Targets were presented in the same sequence at all times. The presentation sequence for left orientation was $0^{\circ}$, right $60^{\circ}$, right $15^{\circ}$ right $45^{\circ}$, and right $30^{\circ}$. For right orientation it was $0^{\circ}$, $45^{\circ}$ left, $15^{\circ}$ left, and $30^{\circ}$ left. The starting position for each shot was $0^{\circ}$, rifle at the ready position.

To insure similar starting position, yellow orientation markers were displayed down range, behind the target pits of Targets 1 and 5. Additionally, a wooden rifle rest was located in front of the shooter so that he could lower the butt to waist level and rest the muzzle on the rifle rest. This insured that each target engagement began from the same starting position. The starting orientations of subjects were alternated so that 10 shooters started the qualification trials oriented to the left and 10 were oriented to the right. This procedure distributed the effects of such variables as fatigue, learning, environmental effects and background foliage across both orientation conditions. Target presentation time was fixed at 1.75 seconds. While the interval between target presentations was usually held at 6 seconds, equipment malfunctions caused occasional delays. When delays of over one minute occurred, the subject was required to repeat the cycle of five targets.

After the qualification trial, the hit/miss data were reduced for the 20 shooters. Subjects were then assigned to one of two vest groups, so that the ability of the two groups was approximately equal.

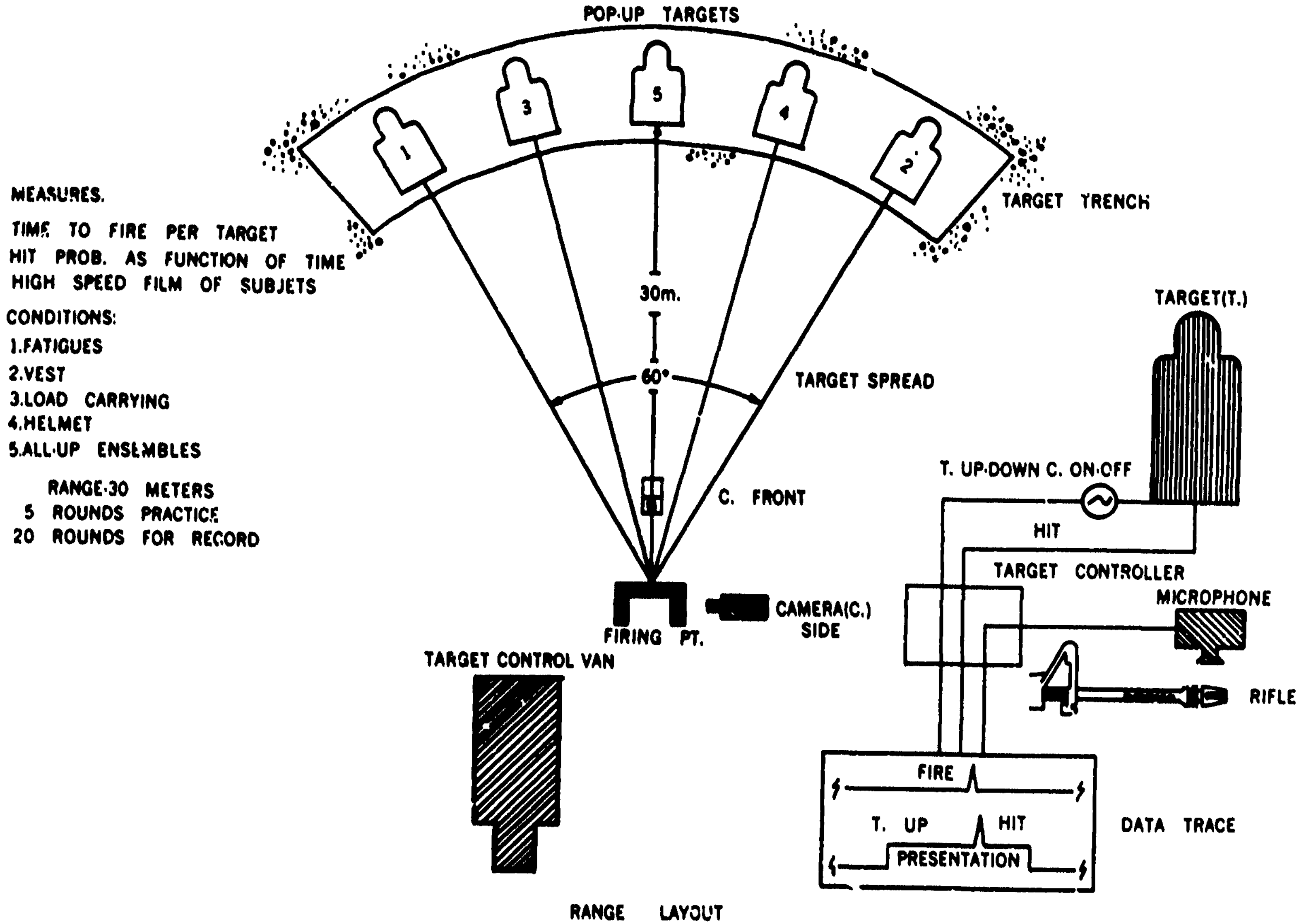


Fig. 5. DIAGRAM OF POP-UP RANGE FACILITY

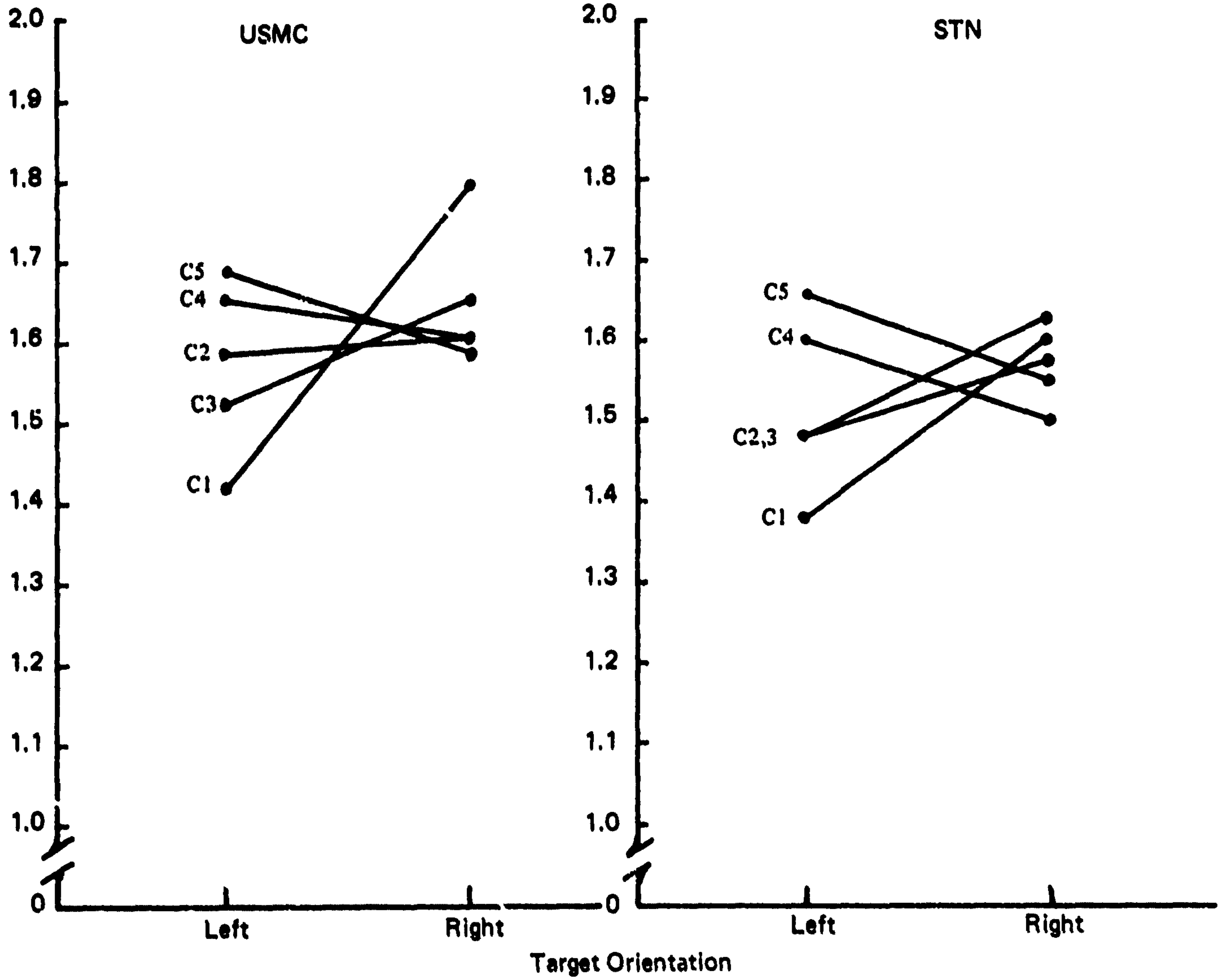


Fig. 6. TIME-TO-FIRE INTERACTION, STANDING POSITION

Three days after qualification, the experiment was begun. The procedure required three days to complete. The experiment was conducted according the same procedures described for the qualification trial, except that each individual fired from both standing and prone positions, 40 rounds in each position. Ten subjects wore STN personnel armor with standard Army load-bearing equipment and 10 wore USMC Doron personnel armor with the same load bearing equipment.

During the experiment, hit/miss and time-to-fire data were collected as described by Corona et al. (1), and the entire procedure was filmed.

Rifle-firing results were analyzed under two headings: standing position and prone position.

### Standing Position

The hit/miss data were reduced and subjected to analysis of variance, repeated measures across dominant hand/non-dominant hand orientation and targets. The results of this analysis appear as Table 16. The main effect for targets ($F = 6.68$ df 4/108, $p < .01$) was the only significant result.

The time-to-fire data were also subjected to analysis of variance repeated measures across orientation and targets. A review of the Summary Table (Table 17) shows a significant vest by orientation interaction ($F = 63$ df, $p < .001$). The components of this interaction are plotted in Figure 6.

The films were reviewed to provide a behavioral measure of the experiment. This review was conducted after the data were analyzed. The films do not show any systematic behavior for subjects equipped with either vest. It was noted, however, that the shoulder cord of the USMC vest was covered by load-bearing equipment on eight out of 10 of the subjects.

Figure 7 displays the relationship between hit probability by target and time to fire. Hits and time to fire shows a high correlation for the USMC group ($r = .85$) and a very low negative correlation for the STN group ($r = -.13$).

The analysis of hit/miss data for qualification trials show there is no significant difference in the shooting ability of the two groups (Table 18).

TABLE 16

Summary of Vest and Control Groups Hit/Miss, Standing Position

| Source of Variation | SS | df | MS | F | p |
|---|---|---|---|---|---|
| Between Subjects | 249.75 | 29 | | | |
| A (Vests) | 3.81 | 2 | 1.90 | | NS |
| Subject within grps (error) | 245.94 | 27 | 9.10 | | |
| Within Subjects | 278.80 | 270 | | | |
| B (Offset) | .85 | 1 | .85 | | NS |
| AB | 6.50 | 2 | 3.25 | 3.15 | NS |
| B x subj w. grps (error b) | 27.86 | 27 | | | |
| C (Targets) | 8.58 | 4 | 2.14 | | |
| AC | 3.86 | 8 | .48 | | |
| C x subj w. grps (error c) | 35.36 | 108 | .32 | 6.68 | * |
| BC | 6.38 | 4 | 1.59 | | NS |
| ABC | 6.58 | 8 | .82 | | NS |
| BC x subj w. grps (error bc) | 195.64 | 108 | 1.81 | | |

## TABLE 17

Summary of Vest X Offset X Target Time to Fire, Standing Position

| Source of Variation | SS | df | MS | F | p |
|---|---|---|---|---|---|
| **Between Subjects** | | | | | |
| A (Vests) | .1630 | 1 | .1630 | 10.58 | $p < .01$ |
| Subject within groups (error) | .2782 | 18 | .0154 | | |
| **Within Subjects** | | | | | |
| B (Offset) | .0938 | 1 | .0938 | 2.96 | NS |
| AB | .0094 | 1 | .0094 | | |
| B x subject within groups (error b) | .5709 | 18 | .0317 | | |
| C (Targets) | .1745 | 4 | .0436 | | |
| AC | 8.5025 | 4 | 2.1256 | 63.07 | $p < .01$ |
| C x subject within groups (error c) | 2.4290 | 72 | .0339 | | |
| BC | .0606 | 4 | .0151 | | |
| ABC | .007 | 4 | .0017 | | |
| BC x subject within groups (error bc) | 2.97 | 72 | .0412 | | |

## TABLE 18

Summary Table for Results of Qualification Trials
(Hit/Miss)

| | SS | df | MS | F | p |
|---|---|---|---|---|---|
| SS Treat | 121.40 | 2 | 60.70 | | |
| SS Error | 2477. | 27 | 91.74 | .66 | NS |
| SS Total | 2598. | 29 | | | |

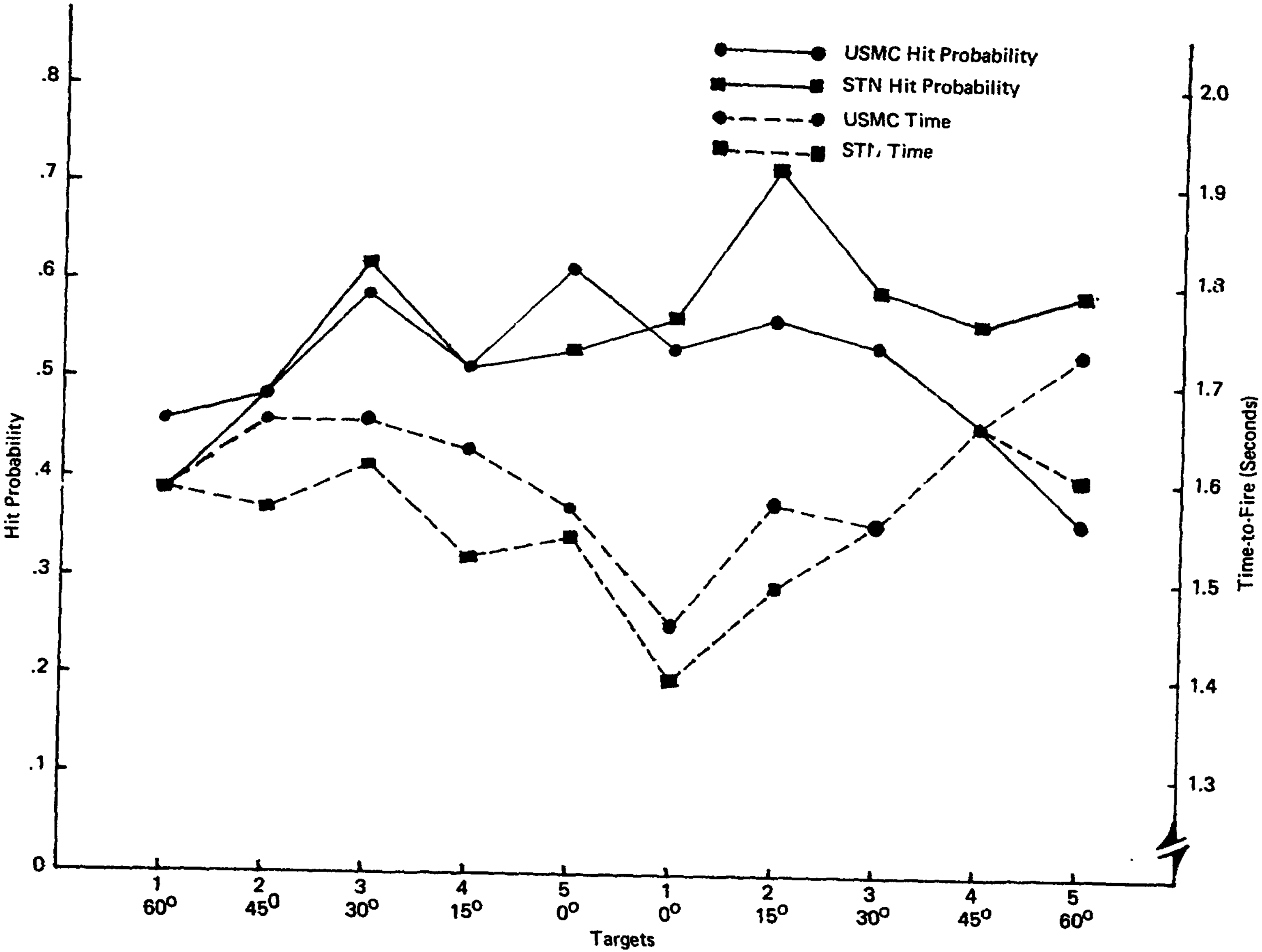


Fig. 7. PLOT OF HIT PROBABILITY AND MEAN TIME TO FIRE, STANDING POSITION

The plot of the vest by orientation interaction (Fig. 6) shows that Target 3 (30$^{o}$ left or right of the shooter) is the point at which the interaction is most clearly seen. In other words, on Targets 1, 2, 4 and 5, the men equipped with the STN vest fired somewhat faster than the group wearing the USMC vest. On Target 3, this relationship breaks down. The STN group was slightly faster when Target 3 appeared to the left. Since the films show no shouldering or other obvious performance problems, the difference must be ascribed to the overall design of the two types of armor. That is to say, that the portion of the interaction associated with the vests must be due to torso movement problems and not to restrictions involving shouldering or reach.

Further, the differences that exist are subtle and may have no practical significance. Inspection of the mean times to fire for the two groups, by targets, shows a range of differences from .14 seconds to .01 second (Fig. 7). The maximum difference may have practical significance, but it is difficult to relate one-hundredth of a second to any behavioral event except an eye blink. Additionally, the accuracy of measurement of such small time differences is questionable. On the other hand, it seems reasonable to assume that an infantryman would appreciate any advantage under battlefield conditions.

Figure 7 also depicts the relationship between hit probability and mean time to fire for the two groups. In general, the USMC group required more time to achieve a lower hit probability. This is not a statistical finding, but it becomes obvious from inspection of the curves. In fact, the overall mean time to fire a given round was 1.61 seconds for the USMC group and 1.54 seconds for the STN group. The hit probability for a given target was .498 for the USMC group and .550 for the STN group. Hits and time-to-fire for the USMC group correlated highly ($r = .85$) while the same variables for the STN group are correlated at a very low level ($r - .-13$).

This correlation further suggests that time was not a factor in engaging targets for the STN group, but may have contributed to the lower hit probability of the USMC group. It might also be suggested that the shooting characteristic of the two groups were different; however, the qualification scores for the groups were found to be not significantly different (Table 18).

## Prone Position

Data for hit/miss and time-to-fire variables for prone firing were reduced and analyzed in several ways. Table 19 represents the summary for analysis of variance of hit/miss data for the USMC, STN, and control conditions. While the main effect for vests is not apparent, targets and offset effects were significant. Further, the offset/target interaction was significant. This interaction is plotted in Figure 8. Additionally, a plot of this interaction at Targets 2, 3 and 4 is presented as Figure 9.

Table 20 presents the analysis of variance summary for time-to-fire data from USMC and STN groups. (Because of equipment malfunction, time-to-fire data for the control group proved unreliable and was not used in this analysis.) As is the case for the hit/miss data, targets and offset main effects are significant. The target/offset interaction is also significant. This interaction is plotted in Figure 10.

Figure 11 represents a plot of mean time to fire and hit probability by targets. A correlation of hit and time-to-fire data shows a high correlation for the USMC group ( $r = .80$), while the correlation is lower for the STN group ($r = .30$).

TABLE 19

Summary of Vest and Control Groups Hit/Miss Prone Position

| Source of Variation | SS | df | MS | F | p |
|---|---|---|---|---|---|
| Between Subjects | 166.5 | 29 | | | |
| A (Vests) | 13.18 | 2 | 6.59 | 1.16 | NS |
| Subject within groups (error) | 153.32 | 27 | 5.67 | | |
| Within Subjects | 373.00 | 270 | | | |
| B (Offset) | 8.96 | 1 | 8.96 | 11.34 | $p < .01$ (7.95) 27/1 |
| AB | .86 | 2 | .43 | --- | |
| B x subject within groups (error b) | 21.58 | 27 | .79 | | |
| C (Targets) | 14.50 | 4 | 3.62 | 5.17 | $p < .01$ (3.41) 108/4 |
| AC | 5.0 | 8 | .62 | --- | |
| C x subject within groups (error c) | 76.58 | 108 | .70 | | |
| BC | 139.73 | 4 | 34.75 | 33.09 | $p < .01$ (3.41) 108/4 |
| ABC | 5.5 | 8 | .68 | --- | |
| BC x subject within groups (error bc) | 113.5 | 108 | 1.05 | | |

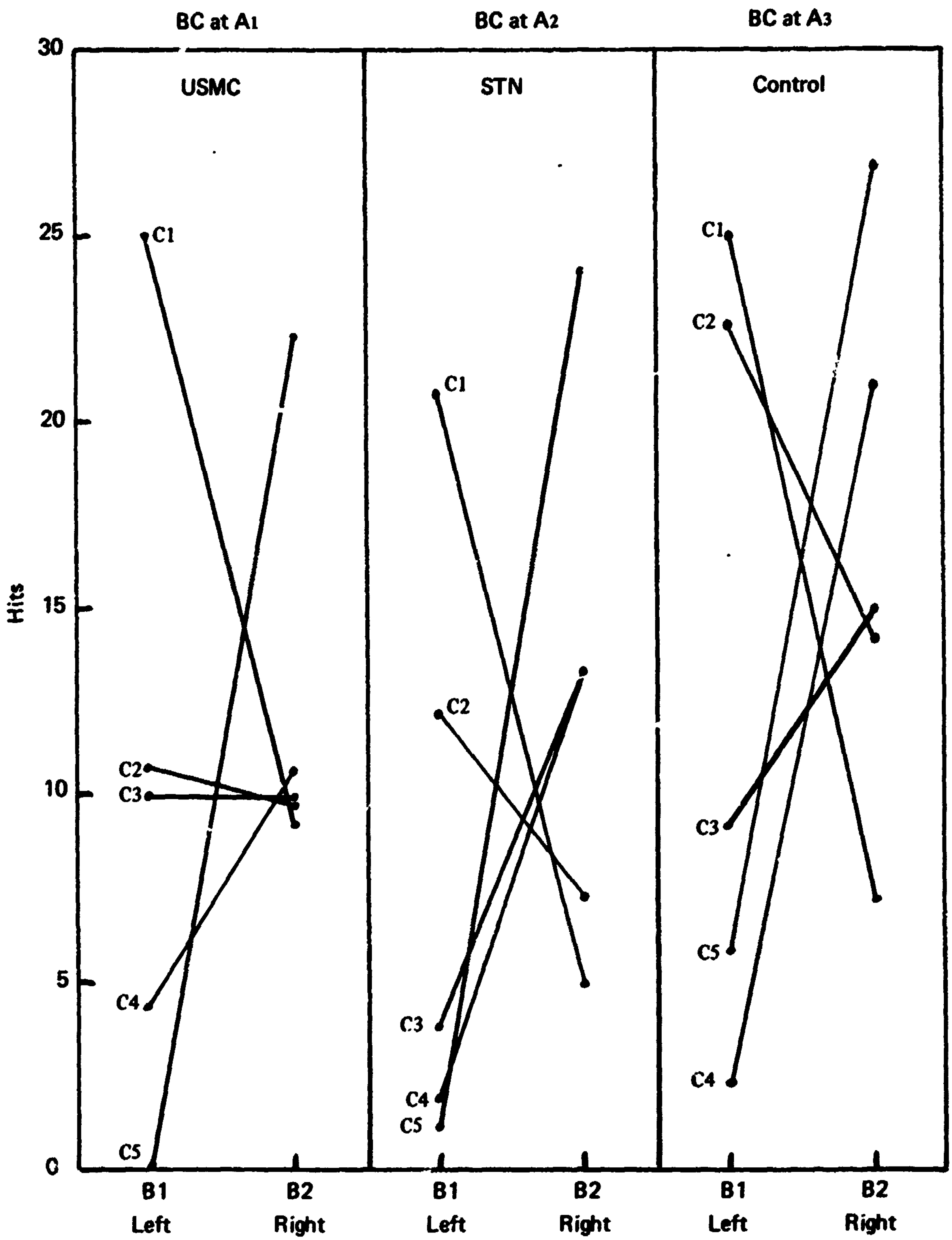


Fig. 8. HIT/MISS INTERACTION, PRONE POSITION

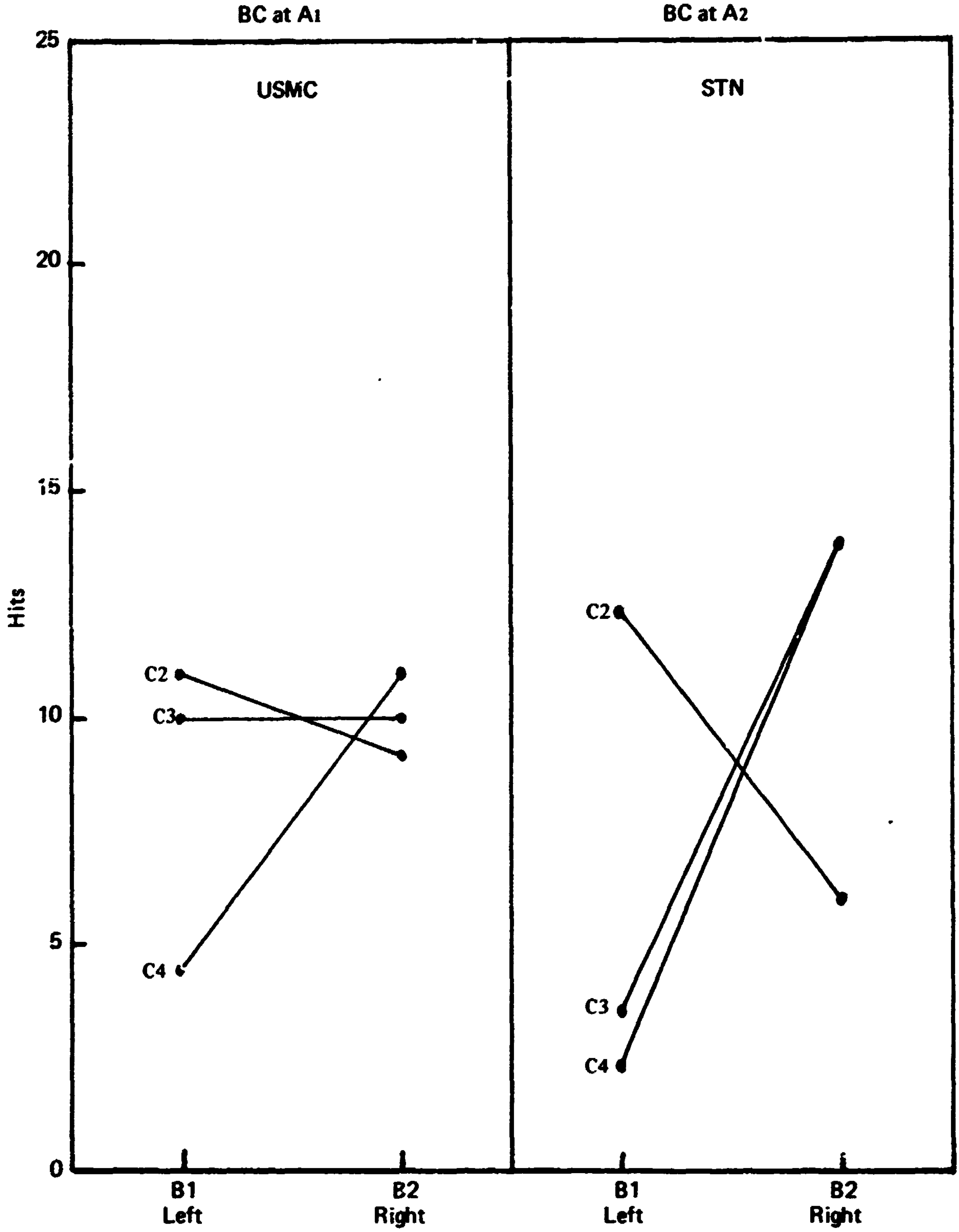


Fig. 9. HIT/MISS INTERACTION AT TARGETS 2, 3 AND 4, PRONE POSITION

TABLE 20

Summary of Time to Fire - Prone Position

| Source of Variation | SS | df | MS | F | p |
|---|---|---|---|---|---|
| **Between Subjects** | | | | | |
| A (Vests) | .3872 | 1 | .3872 | 1.0507 | NS |
| Subject within groups (error) | 6.633 | 18 | .3685 | | |
| **Within Subjects** | | | | | |
| B (Offset) | .1352 | 1 | .1352 | 1.9177 | NS |
| AB | .0288 | 1 | .0288 | | |
| B x subject within groups (error b) | 1.269 | 18 | .0705 | | |
| C (Targets) | 1.9399 | 4 | .4849 | 11.9728 | p < .01 |
| AC | .1746 | 4 | .0436 | | |
| C x subject within groups (error c) | 2.9219 | 72 | .0405 | | |
| BC | 6.6341 | 4 | 1.6685 | 24.3181 | p < .01 |
| ABC | .2654 | 4 | .0663 | | |
| BC x subject within groups (error bc) | 4.9165 | 72 | .0683 | | |

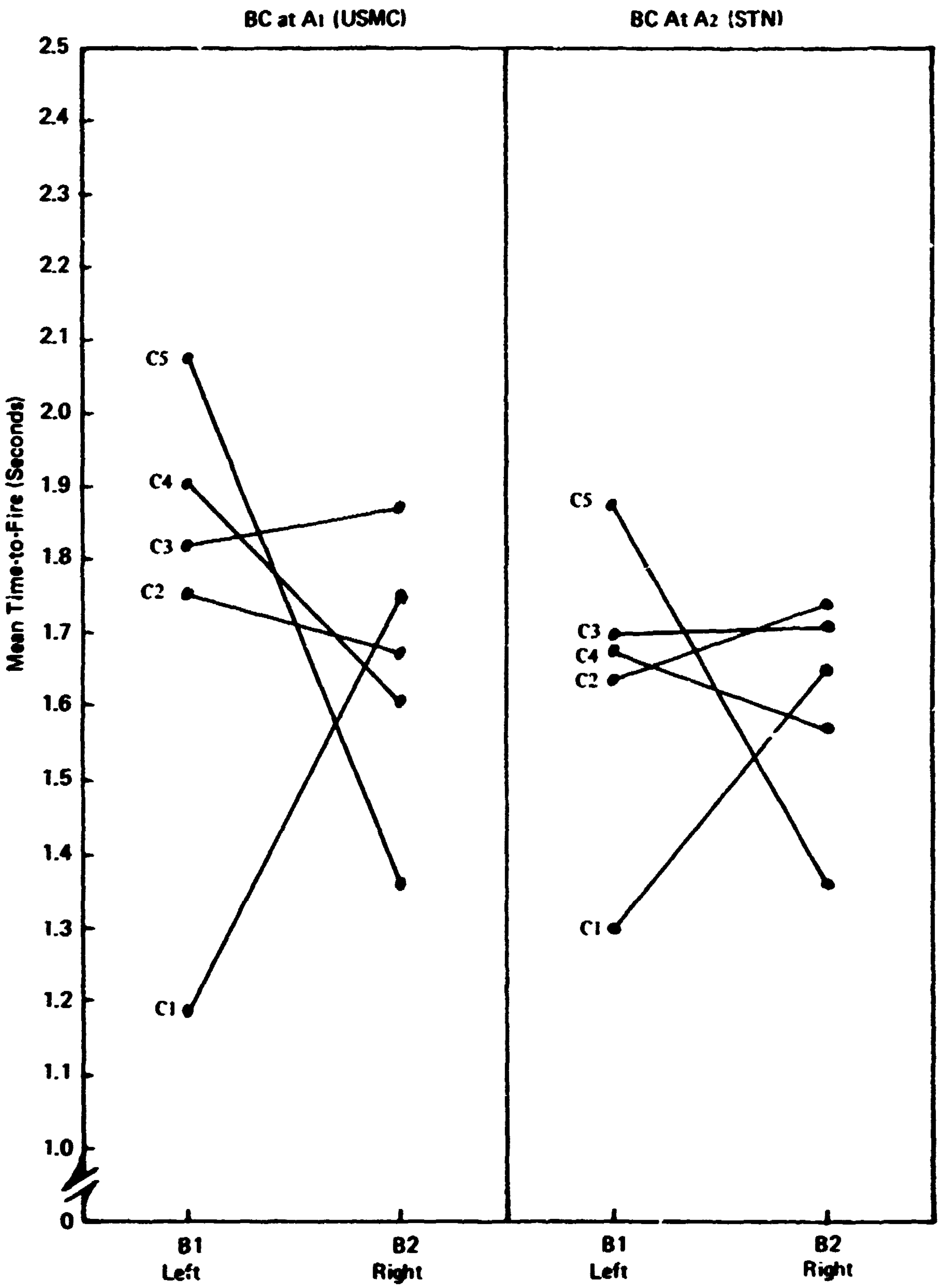


Fig. 10. TIME-TO-FIRE INTERACTION, PRONE POSITION

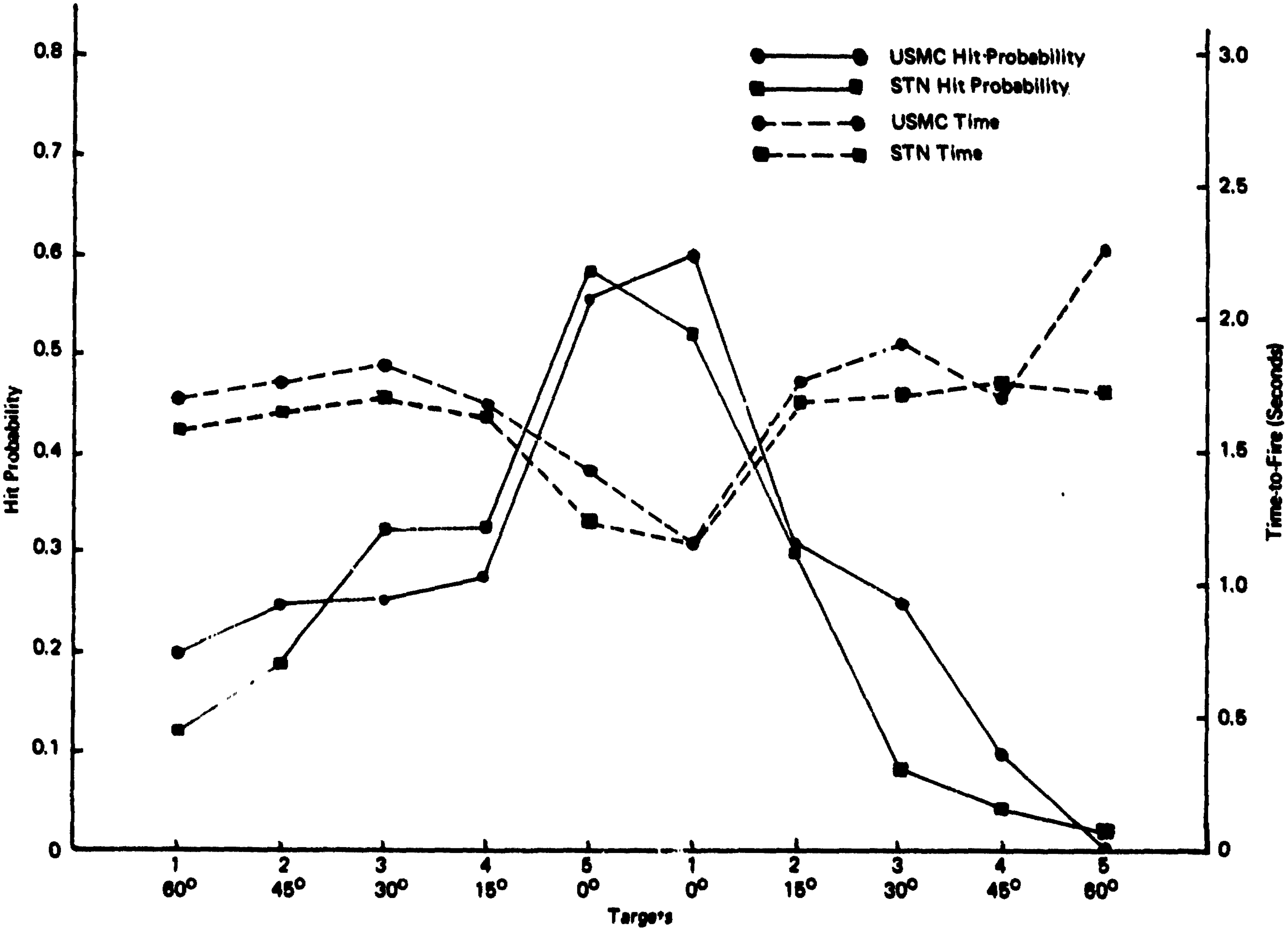


Fig. 11. HIT PROBABILITY AND MEAN TIME TO FIRE, PRONE POSITION

Films of the firing were analyzed to determine if soldiers equipped with candidate armor displayed any behavioral differences during the firing. During the analysis, four man/equipment interactions became apparent. It was observed that several shooters grasped the rifle magazine instead of the forestock. This occurred primarily during the left offset condition. It was also evident that several shooters were shouldering the rifle improperly. This effect occurred primarily in the right offset condition. Shoulder bunching across the back of the subject was observed frequently and a helmet/load-carrying suspenders interaction occurred with many subjects.

Results of the present investigation suggest that there is no overall difference in the firing performance of men equipped with the two types of personnel armor. The significant interactions do provide for points of contrast between the vests. This indicates that while the total performance as to accuracy and time to fire is essentially equal, the components contributing to the interactions affect the shooters in different ways.

To develop this line of reasoning clearly, it is necessary to consider the behavior of the shooter in conjunction with the performance measures used in the overall analysis. Table 21 shows that two consistent problems were experienced by shooters in both vest conditions. One of these problems was grasping the magazine instead of the forestock, because of an inability to reach the forestock. This inability we will call short reach. The other problem was an improper shouldering. The films suggest that when the right-handed shooter is required to fire to his right, the short reach effect is most obvious. Conversely, when the right-handed shooter fires to the left side, shouldering problems become more apparent.

The short-reach effect is exaggerated by the bulk of the armor at the shouldering area. This bulk must be subtracted from the nominal reach of the shooter, since the bulk is between the shooter's shoulder and the rifle butt. The individual grasps the magazine because it is convenient to do so. He is adapting his shooting style to existing conditions. However, the tendency to short-reach may result in increased weapon malfunction from the rearward pressures on the magazine. This is a systems problem and should be considered in the development of both body armor and weapons.

Short reach could explain the apparent differences in the target-by-offset interaction at Targets 3 and 4 (Fig. 9). The USMC group hit Target 3 about equally in left and right offset. At Target 4, the USMC groups' performance dropped off considerably. This may be the result of the onset of short reach at Target 4. The STN group's performance at Targets 3 and 4 is essentially equal. The suggestion is that short reach had developed at Target 3 for the STN group. It is possible that the USMC vest is superior to the STN when the shooter is required to shoot at targets appearing at 30$^{\circ}$ to the shooter's right.

The USMC vest is of the closed-shoulder type. The STN is equipped with an open shoulder overlain with an articulated two-piece shoulder plate. The films show that the articulated shoulder pad of the STN does not function as designed when load-bearing equipment is worn over the armor. In some cases, the pad is forced up and out from the shoulder. This effect exaggerates the short-reach effect because the rifle is now shouldered even farther from the shooter's body.

To summarize the short-reach problem, both vests seem inadequate on targets to the extreme of the shooter's handed side. The USMC seems better than STN up to 30$^{\circ}$. After 30$^{\circ}$ neither vest is satisfactory. The shoulder pad is the primary contributor to short-reach problems with the STN vest.

Having dealt with the short-reach problem, it is necessary also to consider improper shouldering as a contributor to the interaction for both vests. When the shooter fires away from his handed side there is a tendency to shoulder the rifle towards the outside of the shoulder. The shoulder is generally thrust forward to form a cradle for the rifle butt. To achieve proper shouldering on targets appearing at $60^{\circ}$ is difficult under any condition. Adding body armor evidently complicates the problem.

Generally, the shooter equipped with body armor has a difficult time feeling the rifle butt through the armor. Because of this, the USMC vest has a cord sewn to the shouldering area (Fig. 1). This cord allows the shooter to orient the rifle in a good position without feeling the butt at the shoulder. The STN vest has a similar guide in the form of a slight pocket formed by the angle of the shoulder pad and the collar assembly (Fig. 1). When firing to the left at extreme angles ($45^{\circ}$ and $60^{\circ}$) these aids do not seem to be effective. In fact, the cord or pocket seem to be most effective when the shooter is engaging straight-ahead targets.

The shouldering problem is one of frustration. The shooters try to engage the targets to the extreme of their non-handed side initially, but resort to a wild snapshot when they realize the difficulties of firing at the required angle. Many shooters do not even shoulder the rifle. Some men rolled to the side and fired with the rifle oriented in a horizontal instead of a vertical position. In any event, over half of the men in this experiment had shouldering difficulties when firing away from their handed side.

The shouldering effect contributed to the interactions about equally, as far as hit probability is concerned, but there seems to be a difference in vests when time-to-fire data are considered. These results indicate that at Target 3 the STN group fired at about the same speed. At Target 4, a performance decrement occurred. The USMC group suffered the performance decrement at Target 3 and the effect persisted across Targets 4 and 5. This finding suggests that the STN group was able to fire faster throughout the $60^{\circ}$ arc than the USMC group. The USMC group experienced severe problems with the targets away from their handed side. This problem seems to be associated with the arm opening of the USMC vest.

We are now faced with a dichotomous relationship which we need additional information to fully understand. In real-world terms, the vests seem about equal for accuracy of fire while the STN seems to allow quicker firing. In other words, either vest will allow reasonable accuracy when the soldier fires controlled semi-automatic engagements, while the STN would be better for a quick-fire situation. Naturally, it is impossible to predict the circumstances of battle, so it is incumbent on the designer to provide a vest combining the advantages of both armored vests. These advantages seem to be a flexible shoulder area which moves with the shooter, which is relatively thin and highly flexible, and which incorporates some shouldering aid. Further, the arm opening should allow for complete freedom of movement of the arms, especially when the individual is required to reach in front and to the sides.

The quality of the shot, versus the speed of the shot, is very difficult to interrelate. Some relationship between time-to-fire and hit probability can be seen by correlating these two variables. The correlation between time-to-fire and hits for the USMC group is high ($r = .81$). This correlation for the STN group is low ($r = .30$). This comparison indicates that time was more of a factor for the USMC group than for the STN group. While this is not a conclusive finding, it does contribute to the trend which suggests that the STN allows quicker movements than the USMC configuration.

Further analysis of the filmed data reveals two additional problems which should be addressed (Table 21). Both vests seem to interact with the M1 helmet when the shooter is in the prone position. Actually, the interaction occurs between the lower rear excursion of the helmet and the cross member of the load-bearing equipment suspenders. Additionally, extreme bunching occurs across the shoulder area at the rear of the STN vest. This effect tends to accentuate the helmet interaction on the STN vest.

TABLE 21

Summary of Motion Picture Data
Prone Position

| | USMC Group | STN Group |
|---|---|---|
| Behavior | | |
| Poor Shouldering of Rifle | 8 Individuals | 6 Individuals |
| Short Reach | 7 Individuals | 5 Individuals |
| Equipment Interaction | | |
| Helmet/Suspenders | 6 Individuals | 6 Indivudals |
| Bunching at Shoulders | 2 Individuals | 9 Individuals |

The helmet/suspenders interaction is a known deficiency with any vest and, indeed, can be seen in subjects who are dressed in fatigues only. This problem will not be solved only by altering body armor, but must also be addressed in the development of any proposed helmet configuration as well. This interaction must surely contribute to the variance of the experiment but there is no way to estimate the magnitude of the contribution. It is mentioned to point out that neither vest is compatible with the M1 helmet and to emphasize the complicated nature of the interactions reported here.

The bunching effect is somewhat more straightforward (Fig. 12). This problem is seen in nine out of 10 subjects of the STN group, but in only one of the subjects in the USMC group. The films show the interaction of the 10 articulated plates which extend from the shoulders across the back of the neck. The bunching occurs in the prone position and forms a triangularly-shaped portal estimated at seven square inches. This effect exists on both sides so that a total of 14 square inches are left without ballistic protection. Since this portal extends entirely across the shoulders, a surface area estimated at 70 square inches could be exposed on a representative medium-sized man. This is the type of problem that comes to light in field experimentation.

Fig. 12. SHOULDER BUNCHING, STN VEST

## CONSUMER PANEL

A consumer panel was convened and consulted to determine which design characteristics of the two candidate vests receive high user acceptance.

Twenty U. S. Army enlisted infantrymen served as subjects. All but three of these men had served as infantrymen in Southeast Asia.

The panelists traversed part of a standard U. S. Army Physical Training (PT) Course, a Road-March Course, and a Wooden-Terrain Course while wearing the USMC Doron Armored Vest in sizes regular, large and extra large, and the STN Army Armored Vest in sizes small, medium and large, and while carrying the standard Army combat load. Their responses were reported on rating-scale forms.

Upon arrival subjects were given a rating scale and asked to rate the standard nylon fragmentation vest. During the two-week period, subjects participated in each of two events. The events were designed to present subjects with a series of movements representative of combat relevant tasks. The dodge, run and jump and horizontal ladder events of the Standard Army PT Course were used to allow the individuals an opportunity to feel the dynamics of the armor during stressful physical activity. The Road-March and Wooded-Terrain Courses provide the experience of sustained use of armor while marching running and crawling through underbrush, branches and troublesome foliage.

The PT event consisted of a 15-meter dash to the dodge, run and jump. After proceeding through the dodge, run and jump, the men dashed 20 meters and assumed a prone firing position. The men then crawled 20 meters, got back to their feet, and dashed 50 meters to the horizontal ladder. At this point, the men slung arms and completed 14 rungs of the horizontal ladder event. The entire course required an average of one minute and thirty seconds to complete.

Each subject ran the course once with each type of body armor. After the event the men completed a rating scale directed at the mobility characterisiics of the armor.

The cross-country event consisted of a two-mile march. The troops, in squad size units, moved down a gravel road for a quarter-mile, then made a quarter-mile run. The run terminated at the entrance to a wooded area. The men were given a five-minute break at this point. The break was followed by a one-mile march through the woods, which were composed of moderate to heavy brush and some swampy terrain. After leaving the wooded area, the squad was lead down a dirt road for a quarter-mile and ended the event with a quarter-mile run. Because the purpose of this activity was to provide the individual with a set of experiences rather than to control the time or the physical effort exactly, the route through the wooded area varied. The experimenter selected a demanding route through fresh foliage so the individual would move through overhanging branches, thorny vegetation and swamp. At the end of the event, each man completed a rating scale. Each man completed the course twice, once with each armored vest.

On the final day of testing, subjects were organized into two groups, depending on which vest they preferred. The groups were allowed 30 minutes to collaborate and organize their thoughts as to why they preferred their selection. Each group then selected a spokesman to present their views and cite specifics. The groups were then assisted in elaborating on their preferences by open discussion of questions posed by a group of HEL staff personnel. The HEL personnel consisted of two members of the research team conducting the evaluation and two professionals not involved in the program.

The rating-scale results were reduced and submitted to analysis of variance. Each bipolar adjective pair was analyzed independently. The results of these analyses are presented in Tables 22 through 28. The only significant effect was found to be associated with the weight of the two vests (heavy-light). The semantic profiles for both vests and the STD B vest are plotted in Figure 13.

The consumer-panel discussion was recorded and analyzed. The group of 18 soldiers participating in this discussion selected the STN vest as the better of the two vests tested by a vote of 14 to four. The groups' specific likes and dislikes about both vests appear in Table 29.

Interviews revealed certain points of agreement by the entire group. Everyone felt the STN was cooler and lighter than the USMC vest. Everyone agreed that if ordered to wear either vests, they would carry out that order. It was also agreed that they would rather carry an equivalent weight of ammunition than either vest. Further, every man felt his performance as an infantryman would not be adversely affected if required to wear body armor.

The results of the analysis of rating-scale data show that while 14 out of 18 men preferred the STN vest over the USMC vest, this preference was not based on a belief that the STN was the optimum design in body armor. The semantic profiles for the two vests show this clearly. For almost every bipolar combination the STN is rated higher than the USMC vest, but this difference in most cases is small and not significantly different. This finding is consistent with the other results presented in this report. A consistent trend has emerged, indicating that the good points of each vest are confounded by some other less desirable feature.

The consumer-panel discussion makes clear that the men felt something should be done about the shoulder assembly of the STN vest. The group selecting the STN vest focused a good bit of attention on the need to improve the articulated shoulder of the vest. The group selecting the USMC rejected the STN for this reason.

It is also clear from the discussion that the quick-release capability of the Velcro fastening system meets with approval. The Velcro strip which closes the front of the STN seems to fill this need as far as the panel was concerned.

The listing of specific likes and dislikes about the two vests (Table 29) shows that the STN has several desirable and undesirable features. It is interesting to note that all of the men preferring the USMC vest wore the regular USMC and the medium-sizes STN vest. Further, the features cited as undesirable in the STN group were mentioned by both groups.

The findings regarding user acceptance indicate that neither vest will receive high user acceptance. The findings do suggest that an improved STN vest will receive better acceptance than the USMC vest. The panel focused attention on the shoulder of the STN, a quick-release capability and the weight of the USMC vest. Finally, the results seem to agree with the findings of the previous chapters in that there is a tendency to select the STN on the basis of potential rather than on any specific qualitative difference between the two configurations tested.

TABLE 22

Summary of Semantic Results, Best-Worst

| Source | SS | df | MS | F | Sig. |
|---|---|---|---|---|---|
| SS between subjects | 39.80 | 14 | 2.84 | 1.74 | |
| SS within subjects | 24.50 | 15 | 1.63 | | |
| SS vests | 1.63 | 1 | 1.63 | | |
| SS error | 22.87 | 14 | 1.63 | | |
| SS totals | 64.30 | 29 | | | |

TABLE 23

Summary of Semantic Results, Comfortable-Uncomfortable

| Source | SS | df | MS | F | Sig. |
|---|---|---|---|---|---|
| SS between subjects | 47.47 | 14 | 3.59 | | |
| SS within subjects | 35.50 | 15 | 2.36 | | |
| SS vests | 2.7 | 1 | 2.7 | | |
| SS error | 32.8 | 14 | 2.34 | | |
| SS totals | 82.97 | 29 | | | |

TABLE 24

Summary of Semantic Results, Neat-Sloppy

| Source | SS | df | MS | F | Sig. |
|---|---|---|---|---|---|
| SS between subjects | 29.80 | 14 | 2.13 | | |
| SS within subjects | 47.00 | 15 | 3.13 | | |
| SS vests | 2.13 | 1 | 2.13 | | |
| SS error | 44.87 | 14 | 3.2 | | |
| SS totals | 76.80 | 29 | | | |

## TABLE 25

Summary of Semantic Results, Slips-Clings

| Source | SS | df . | MS | F | Sig. |
|---|---|---|---|---|---|
| SS between subjects | 26.80 | 14 | 1.91 | 1.81 | |
| SS SS within subjects | 15.5 | 15 | 1.03 | | |
| SS vests | .83 | 1 | .83 | | |
| SS error | 14.67 | 14 | 1.05 | | |
| SS totals | 42.30 | 29 | | | |

## TABLE 26

Summary of Semantic Results, Heavy-Light

| Source | SS | df | MS | F | Sig. |
|---|---|---|---|---|---|
| SS between subjects | 45.67 | 14 | 3.26 | 2.71 | .05 |
| SS within subjects | 33.00 | 15 | 2.2 | 1.83 | NS |
| SS vests | 16.13 | 1 | 16.13 | 13.44 | .01 |
| SS error | 16.87 | 14 | 1.2 | | |
| SS totals | 78.67 | 29 | | | |

## TABLE 27

Summary of Semantic Results, Balanced Unbalanced

| Source | SS | df | MS | F | Sig. |
|---|---|---|---|---|---|
| SS between subjects | 33.87 | 14 | 2.42 | 1.22 | |
| SS within subjects | 29.50 | 15 | 1.96 | | |
| SS vests | 1.63 | 1 | 1.63 | | |
| SS error | 27.60 | 14 | 1.97 | | |
| SS totals | 63.37 | 29 | | | |

TABLE 28

Summary of Semantic Results, Tight-Loose

| Source | SS | df | MS | F | Sig. |
|---|---|---|---|---|---|
| SS between subjects | 25.47 | 14 | 1.82 | 2.21 | |
| SS within subjects | 11.50 | 15 | .76 | | |
| SS vests | .03 | 1 | .03 | | |
| SS error | 11.47 | 14 | .82 | | |
| SS totals | 36.97 | 29 | | | |

TABLE 29

Summary of Consumer Panel Discussion

| Good Points | Bad Points |
|---|---|
| **STN** | |
| (a) lightweight | (a) shoulder epaulet binding |
| (b) better ventilation | (b) collar retains heat |
| (c) form fitting | (c) armpit restrictions |
| (d) quick release | (d) elastic bands |
| | (e) makes shoulders sore |
| | (f) noisy |
| | (g) not flexible enough in the stomach area |
| **USMC** | |
| (a) less restriction at the shoulder | (a) heavy |
| | (b) hot |
| | (c) ballistic plates loose in pockets |
| | (d) sized too large |
| | (e) collar stiff |
| | (f) makes shoulders sore |
| | (g) pinches at the sides |
| | (h) armpits tight |
| | (i) bulky |

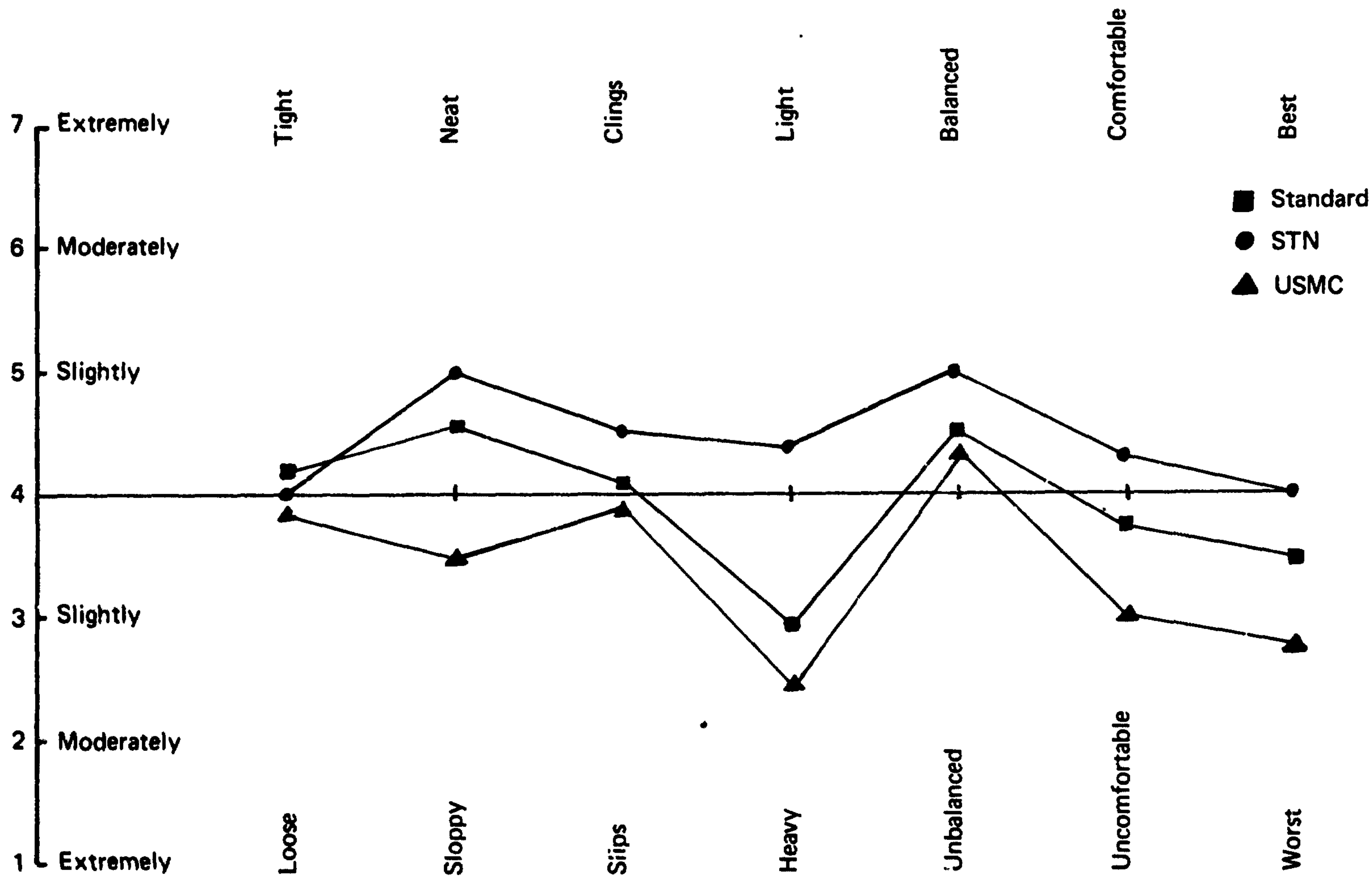


Fig. 13. SEMANTIC PROFILE, STN AND USMC VESTS

## DISCUSSION

The series of tests provided several interrelated facts which indicate trends but do not attribute a clear-cut superiority to either vest The STN vest, as presently configured, is not suitable from a human engineering point of view. However, the STN vest has potential for further development which is not equalled by the USMC configuration.

The USMC vest has closed shoulders, a small neck opening, small arm openings and a loose-fitting waist. The STN has open shoulders, a somewhat larger neck opening, larger arm openings and a fitted waist. The problems identified for the USMC vest have been associated with the neck and arm openings. Because of the loose-fitting waist, increasing the USMC arm and neck openings will cause an exceedingly unstable vest.

The USMC vest is a good ballistic vest. From a human engineering point of view it is lacking, but most armor configurations are less than perfect in this regard. If the STN configuration tested in this evaluation were the final design, the USMC vest would be the preferred configuration since it has been used by troops in combat. However, past research with another articulated titanium nylon vest (4) indicates that many of the problems found in the STN configuration are not insurmountable.

To bring the solutions of some of the STN problems into focus, the designer must look to the 135-plate titanium nylon ICM Protective Armored Vest (T61-4). The 135-plate vest was intended to provide unrestricted mobility to the infantry soldier. This vest is extremely flexible because of the high number of articulations. Unfortunately, there seem to be too many articulations to provide practical production of the device, and the durability of the vest is not good. Further, troops complain about pinching on the torso because the plates have a tendency to dig into the body, especially when the individual quickly assumes the prone firing position. These problems notwithstanding, the 135-plate configuration is superior to the STN in the problem areas evident during these investigations.

Specifically, the shoulder-neck interaction found in the STN is not found in the 135-plate configuration. While the outward appearance of the two vests is similar, the shoulder-pad assemblies of the 135-plate vest contain six articulations compared to the three-plate shoulder pad of the STN. Other STN problem areas not seen in the 135-plate configuration are (a) stomach-plate lock or (b) shoulder bunching. Because these problems have been solved with the T61-4 vest, it is reasonable to assume that many of the other STN problems can be solved by existing methodology.

This investigation has demonstrated that the STN vest in its present design is unacceptable from a human engineering point of view. According to AR70-10 (7), any design defect is considered a deficiency. The shoulder bunching in the STN is a definite design defect and, therefore, a deficiency. Additionally, several shortcomings were noted in the evaluation. (References to deficiencies and shortcomings are consistent with the definitions of AR70-10.)

The deficiency and shortcomings can be summarized as follows:

STN Deficiencies

Shoulder Bunching

This effect indicates improper design since the bunching occurs to some extent in nine out of 10 men tested. The effect can be seen in men wearing all three sizes of the vest.

STN Shortcomings

Articulated Shoulder Pad

These pads cause discomfort and detract more from the overall compatibility of the vest than any other feature of the 48-plate configuration.

Elastic Side Panels

The elastic panels do not shear enough. Elastic drawstrings will provide better shearing at the sides and, according to Natick Laboratories' personnel, assist in minimizing the effects of shoulder bunching.

Vest Length

The front length of the vest causes discomfort to persons in the seated or crouched position. Since the vest will be worn by vehicle operators and individuals being transported in vehicles, this finding is extremely important.

Vest Ride-Up

While the STN vest compares favorably with the USMC vest as far as ride-up is concerned, the STN is not optimum in this regard.

Auxillary Opening

The arm opening is the same size for each vest size Further, a hard seam is located around the periphery of the opening. The size of the opening can be seen to cause binding and restriction, while the hard seam is uncomfortable.

The potential for altering the design of the STN is good. The number of titanium plates selected for this articulated design is not fixed at 48. Indeed, during development several prototypes were fabricated and various plate arrangements were used. The decision to use 48 plates was based on the assumption that the STN configuration provided unrestricted mobility for infantrymen. HEL does not agree with this decision; however, this evaluation suggests that certain modifications can be made which will bring the basic 48-plate design to a par with 135-plate nylon/titanium vest.

## CONCLUSIONS

To summarize the overall finding of this evaluation, neither of the two vests evaluated compare favorably with the 135-plate nylon/titanium vest as far as mobility is concerned. To correct the problems identified in the USMC vest would probably create more problems of even greater magnitude, because the tight-fitting neck and arm openings provide most of the stability to the present vest design. The STN also presents problems, but most of these problems are not found in the 135-plate configuration nylon/titanium vest. Therefore, it is reasonable to assume the STN problems can be solved through application of existing technology.

## RECOMMENDATIONS

The shoulder area of the STN seems to be the area most in need of redesign. Shoulder problems were seen in rifle firing, exercises and dynamic anthropometrics, and they dominated the discussion of consumer panel. The articulated shoulder does not function as designed when load-bearing equipment is worn over the garment. Bunching behind the shoulders raises the profile and leaves the shoulders without ballistic protection. The shoulder plates drive into the collar, causing discomfort and restricted mobility when the arms are raised over shoulder height. By way of contrast, checks of the 135-plate nylon/titanium vest shows no shoulder bunching, better shouldering of weapons, and little restrictions or discomfort during exercise.

The shoulder pad of the STN must be altered or removed to correct the problem. If the pad is removed, the shoulder area will be left without ballistic protection or the ballistic protection will be decreased by substituting ballistic nylon over the shoulder. If ballistic nylon is used to replace the pad, the vest will become a closed-shoulder design. There is enough evidence in the findings of this report to suggest that the closed-shoulder design is not the solution to shoulder articulation problems. Comparing the exercise results of the two vests tested, shows that, while the problem areas differ for the two vests problems occur with approximately equal frequency. Therefore, the STN shoulder pad must be altered to eliminate the interaction.

The solution to the problem seems to be replacing the STN three-plate pad design with the six-plate pad design found in the 135-plate nylon/titanium vest. This modification will control the shoulder/neck interaction when the vest is worn without load-bearing equipment. This is not the final answer since the articulation of the pad will still be disrupted when load-bearing equipment is added. The simplest method of eliminating the load-bearing equipment/shoulder-pad interaction is to provide for passing the suspenders of the load-bearing equipment under the pad. This can be accomplished by providing snaps on the pads so that they can be raised to allow the suspenders to be placed directly on the shoulders. When the snaps are secured the individual will be equipped with a compatible body armor/load-bearing equipment ensemble. This arrangement will also provide the soldier with a two-action, quick-release, for removing the armor and load-gearing equipment. That is to say, that by opening the Velcro front flap and pistol belt buckle, the infantryman will be free of vest and load-bearing equipment simultaneously. This quick-release capability was discussed by the consumer panel and determined to be a very important feature of body armor to be used by combat troops.

The substitution of the six-plate shoulder-pad assembly will probably help to control shoulder bunching; however, this bunching may require additional corrective action. Review of the films of this effect shows that the shoulder bunching begins at a line across the back, extending from the lower aspect of the arm openings on either side of the vest. A natural break exists at this point. Plates C, K and S ride up under plates F, L, N and V. In turn, plates D, E, M, P, V and T buckle at their articulation with F. L, N and V. The latter effect causes the characteristic triangular opening across the back of the shoulders. Armor specialists from Natick Laboratories suggest that this effect occurs because the elastic side panels of the vest do not allow enough movement between the front and back sections of the vest. Therefore, the elastic side panels should be replaced with elastic drawstrings similar to those found in the 135-plate nylon/titanium configuration. If this alteration does not control bunching, rearticulation of the rear shoulder area is indicated.

The exercise routines indicate that the stomach area of the present vest requires some modification. Men in the seated and crouching positions experience restriction when bending forward. Vehicle operators and engineering personnel will be most affected by this problem. Two solutions are obvious: the stomach area should either be shortened or rearticulated. Inspection of Table 1 reveals that the length of the vest is the same for all sizes, so the length of the vest is not critical as to size. The stomach problem indicates that vest length is critical in the seated and crouching positions. Stomach-plate restriction probably results from vest length and may be aggravated by using the same length for all vest sizes. If altering the length does not reduce the affects of stomach-plate lock, rearticulation will be necessary.

Yet another problem area was identified in the exercise routines. Evidently the seam under the arm opening results in discomfort. Natick Laboratories' personnel suggest this four-ply seam can be altered so that discomfort associated with forward-type reaching movements can be controlled. However, inspection of Table 1 shows that the arm openings are the same circumference for all these vest sizes. It is possible that this fact contributes to the discomfort associated with forward reaching movements for individuals wearing certain vest sizes.

Finally, the pockets and grenade hangers of the STN are not compatible with load-bearing equipment (8). This is a minor point from the human engineering point of view, but the inclusion of pockets must contribute to the overall cost of the garment. If these pockets are not usable, the expense is wasted. In any case the pockets should be relocated so they can be utilized along with load-bearing equipment.

If the recommendations presented in this report are followed, the STN vest will provide the U. S. Army infantryman with a functional design capable of providing state-of-the-art ballistic protection. This final vest should also be suitable for use [illegible] and for combat support troops. The STN with changes should receive better user acceptance than other vest configurations. There is every reason, however, to expect that any body armor will be considered a nuisance by combat troops. Nevertheless, the STN vest with the recommended changes will provide a significantly improved body-armor design suitable for use in the field.

## REFERENCES


1. Corona, B., Ellis, P., Jon:s, R. D., Randall, R. D., & Scheetz, H. A. Evaluation of rifle firing behavior of troops equipped with body armor: A pilot study. Technical Note 14-72, U. S. Army Human Engineering Laboratory, Aberdeen Proving Ground, Md., 1972.

2. Department of the Army. Test and evaluation during development and acquisition of materiel. Army Regulation 70-10, Washington, D. C., September 1971.

3. Department of the Army. Wound ballistics. Washington, D. C., 1962.

4. Lamber [illegible], Burns, M., & Barron, E. Technical Report 69-70-CE, U. S. Army Natick Laboratories, Natick, Mass., April 1969.

5. Scheetz, H. A., Corona, B., Ellis, P., Jones, R. D., & Randall, R. B. Application of the semantic differential technique in design and evaluation of helmets and body armor. U. S. Army Human Engineering Laboratory, Aberdeen Proving Ground, Md., (unpublished).

6. Torre, J., Kramer, R., & Lucas, J. Pistol effectiveness studies. U. S. Army Human Engineering Laboratory, Aberdeen Proving Ground, Md., (in press).

7. U. S. Army Materiel Command. U. S. Army Materiel Command Five-Year Personnel Armor System Technical Plan. Washington, D. C., March 1971.

8. Weir, W. R. Design and development of an articulated armor garment. Technical Report TS-130, U. S. Army Natick Laboratories, Natick, Mass., March 1965.

9. White, R. M., & Churchill, E. The body size of soldiers, U. S. Army Anthropometry - 1966. Technical Report 7 -51-CE, U. S. Army Natick Laboratories, Natick, Mass., December 1971.

## APPENDIX

## RESULTS OF THE MEASUREMENT SURVEY

### TABLE 1A

Measurement Seated Chest Depth (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o. LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 7.83 | 0.96 | 7.92 | 10.17 | 9.83 | 11.75 |
| Titanium Medium | 9.54 | 0.51 | 9.69 | 10.77 | 11.40 | 12.27 |
| Titanium Large | 11.25 | 1.03 | 11.25 | 11.94 | 13.06 | 13.56 |
| Marine Corps Medium | 9.10 | 0.76 | 9.21 | 10.69 | 10.92 | 12.38 |
| Marine Corps Large | 10.06 | 0.44 | 10.19 | 10.88 | 11.81 | 12.81 |
| Marine Corps Extra Large | 12.25 | 0.26 | 12.25 | 12.50 | 14.25 | 14.37 |

## TABLE 2A

Measurement Seated Stomach Depth (Inches)

| Vest Size Grouping | Nude Mean | Nude S.D. | Fatigues w/o LBE | Fatigues w/LBE | Fatigues and Vest w/o LBE | Fatigues and Vest w/LBE |
|---|---|---|---|---|---|---|
| Titanium Small | 8.58 | 0.94 | 8.75 | 12.25 | 10.83 | 13.92 |
| Titanium Medium | 9.38 | 0.48 | 10.42 | 13.58 | 12.13 | 14.44 |
| Titanium Large | 12.81 | 1.51 | 12.81 | 14.88 | 11.56 | 16.56 |
| Marine Corps Medium | 9.58 | 0.65 | 9.98 | 13.29 | 12.31 | 14.54 |
| Marine Corps Large | 11.00 | 0.62 | 11.19 | 13.75 | 14.19 | 16.31 |
| Marine Corps Extra Large | 14.13 | 0.79 | 14.00 | 15.75 | 16.13 | 17.00 |

## TABLE 3A

Measurement Standing Stomach Circumference (Inches)

| Vest Size Grouping | Nude Mean | Nude S.D. | Fatigues w/o LBE | Fatigues w/LBE | Fatigues and Vest w/o LBE | Fatigues and Vest w/LBE |
|---|---|---|---|---|---|---|
| Titanium Small | 28.50 | 0.41 | 19.50 | 51.33 | 39.33 | 58.67 |
| Titanium Medium | 34.10 | [illegible] | 35.15 | 58.06 | 43.29 | 60.38 |
| Titanium Large | 43.63 | 5.58 | [illegible] | 62.63 | 50.75 | 65.00 |
| Marine Corps Medium | 32.50 | 2.73 | 33.63 | 56.33 | 43.40 | 60.48 |
| Marine Corps Large | 35.06 | 9.55 | 38.44 | 59.75 | [illegible] | 65.00 |
| Marine Corps Extra Large | [illegible] | 4.25 | 48.50 | 65.00 | 54.50 | 67.50 |

## TABLE 4A

Measurement Standing Stomach Depth (Inches)

| Vest Size Grouping | Nude Mean | Nude S.D. | Fatigues w/o LBE | Fatigues w/LBE | Fatigues and Vest w/o LBE | Fatigues and Vest w/LBE |
|---|---|---|---|---|---|---|
| Titanium Small | 7.09 | 0.21 | 7.01 | 13.96 | 10.80 | 14.38 |
| Titanium Medium | 8.20 | 0.53 | 8.38 | 15.82 | 12.11 | 15.98 |
| Titanium Large | 11.53 | 1.69 | 11.40 | 15.82 | 14.26 | 27.32 |
| Marine Corps Medium | 7.87 | 0.64 | 7.95 | 15.45 | 12.06 | 16.62 |
| Marine Corps Large | 9.38 | 0.87 | 9.63 | 16.09 | 13.50 | 17.80 |
| Marine Corps Extra Large | 12.89 | 1.24 | 12.62 | 14.90 | 15.41 | 18.01 |

## TABLE 5A

Measurement Standing Stomach Width (Inches)

| Vest Size Grouping | Nude Mean | Nude S.D. | Fatigues w/o LBE | Fatigues w/LBE | Fatigues and Vest w/o LBE | Fatigues and Vest w/LBE |
|---|---|---|---|---|---|---|
| Titanium Small | 9.52 | 0.08 | 8.71 | 17.18 | 12.22 | 17.40 |
| Titanium Medium | 10.97 | 0.83 | 10.98 | 17.10 | 13.85 | 18.44 |
| Titanium Large | 14.20 | 1.87 | 13.93 | 29.67 | 16.12 | 20.26 |
| Marine Corps Medium | 10.57 | 0.97 | 10.52 | 16.99 | 13.35 | 18.73 |
| Marine Corps Large | 12.03 | 0.75 | 11.52 | 18.25 | 14.72 | 19.93 |
| Marine Corps Extra Large | 15.75 | .42 | 15.41 | 21.10 | 17.03 | 20.77 |

TABLE 6A

Measurement Standing Eye Height (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 64.50 | 0.89 | 65.75 | 65.75 | 65.75 | 65.75 |
| Titanium Medium | 64.88 | 3.22 | 65.94 | 65.94 | 65.94 | 65.94 |
| Titanium Large | 65.75 | 1.67 | 66.69 | 66.69 | 66.69 | 66.69 |
| Marine Corps Medium | 65.10 | 3.01 | 66.21 | 66.21 | 66.21 | 66.21 |
| Marine Corps Large | 65.13 | 5.11 | 66.13 | 66.13 | 66.13 | 66.13 |
| Marine Corps Extra Large | 64.13 | 0.71 | 65.00 | 65.00 | 65.00 | 65.00 |

TABLE 7A

Measurement Neck Circumference (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 14.08 | 0.32 | 14.08 | 14.08 | 14.08 | 14.08 |
| Titanium Medium | 14.94 | 0.44 | 14.94 | 14.94 | 14.94 | 14.94 |
| Titanium Large | 17.06 | 0.36 | 17.06 | 17.06 | 17.06 | 17.06 |
| Marine Corps Medium | 14.79 | 0.58 | 14.79 | 14.79 | 14.79 | 14.79 |
| Marine Corps Large | 15.87 | 1.32 | 15.87 | 15.87 | 15.87 | 15.87 |
| Marine Corps Extra Large | 17.00 | 0.26 | 17.00 | 17.00 | 17.00 | 17.00 |

TAB[illegible]A

Measurement Standing [illegible]ircumference (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 33.83 | 0.67 | 35.0[illegible] | 35.25 | 35.00 | 35.33 |
| Titanium Medium | 38.73 | 2.27 | 40.19 | 40.71 | 39.85 | 40.38 |
| Titanium Large | 44.69 | 2.45 | 45.50 | 48.06 | 45.38 | 45.44 |
| Marine Corps Medium | 37.29 | 2.75 | 38.77 | 39.23 | 38.37 | 38.65 |
| Marine Corps Large | 42.19 | 1.79 | 43.00 | 43.44 | 42.40 | 43.06 |
| Marine Corps Extra Large | 45.75 | 2.75 | 46.75 | 51.38 | 47.00 | 47.38 |

TABLE [illegible]A

Measurement Standing W[illegible]t Front (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 14.67 | 0.28 | | | | |
| Titanium Medium | 15.23 | 0.56 | | | | |
| Titanium Large | 16.38 | 0.87 | | | | |
| Marine Corps Medium | 15.10 | 0.53 | | | | |
| Marine Corps Large | 15.50 | 0.32 | | | | |
| Marine Corps Extra Large | 17.[illegible] | 1.00 | | | | |

TABLE 10A

Measurement Standing Sternal Notch to Chin (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 3.46 | 0.23 | | | | |
| Titanium Medium | 3.46 | 1.17 | | | | |
| Titanium Large | 2.73 | 0.37 | | | | |
| Marine Corps Medium | 3.59 | 0.39 | | | | |
| Marine Corps Large | 2.71 | 0.39 | | | | |
| Marine Corps Extra Large | 2.68 | 0.08 | | | | |

TABLE 11A

Measurement Neck Width (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 3.91 | 0.22 | | | | |
| Titanium Medium | 4.11 | 0.24 | | | | |
| Titanium Large | 4.67 | 0.09 | | | | |
| Marine Corps Medium | 4.07 | 0.30 | | | | |
| Marine Corps Large | 4.32 | 0.31 | | | | |
| Marine Corps Extra Large | 4.69 | 0.06 | | | | |

## TABLE 12A

Measurement Standing Chest Depth (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 7.63 | 0.38 | 7.56 | 8.91 | 10.66 | 10.38 |
| Titanium Medium | 9.40 | 0.59 | 9.46 | 9.75 | 11.72 | 12.01 |
| Titanium Large | 10.94 | 1.02 | 10.92 | 11.32 | 13.56 | 13.74 |
| Marine Corps Medium | 8.98 | 0.88 | 8.98 | 9.51 | 11.32 | 11.31 |
| Marine Corps Large | 9.83 | 0.33 | 9.97 | 10.19 | 12.19 | 12.73 |
| Marine Corps Extra Large | 11.89 | 0.35 | 11.65 | 12.34 | 14.25 | 15.10 |

## TABLE 13A

Measurement Seated Eye Height (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 30.30 | 0.22 | 30.27 | 30.27 | 30.27 | 30.27 |
| Titanium Medium | 31.55 | 1.97 | 31.53 | 31.53 | 31.53 | 31.53 |
| Titanium Large | 31.55 | 1.00 | 31.50 | 31.50 | 31.50 | 31.50 |
| Marine Corps Medium | 31.54 | 1.75 | 31.51 | 31.51 | 31.51 | 31.51 |
| Marine Corps Large | 31.13 | 1.59 | 30.59 | 30.59 | 30.59 | 30.59 |
| Marine Corps Extra Large | 30.60 | 0.30 | 30.70 | 30.70 | 30.70 | 30.70 |

TABLE 14A

Measurement Seated Chest Circumference (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 33.58 | 0.69 | 34.17 | 36.08 | 39.92 | 40.42 |
| Titanium Medium | 39.17 | 1.28 | 39.90 | 40.63 | 44.69 | 45.63 |
| Titanium Large | 45.81 | 2.87 | 46.19 | 47.81 | 50.81 | 51.81 |
| Marine Corps Medium | 37.71 | 2.61 | 38.58 | 39.38 | 43.77 | 44.50 |
| Marine Corps Large | 41.69 | 1.59 | 42.00 | 37.29 | 47.38 | 48.69 |
| Marine Corps Extra Large | 48.50 | 0.50 | 48.25 | 50.50 | 53.38 | 54.50 |

TABLE 15A

Measurement Seated Stomach Circumference (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 28.92 | 0.48 | 30.00 | 49.67 | 39.67 | 55.08 |
| Titanium Medium | 34.73 | 2.00 | 36.33 | 55.15 | 43.33 | 58.50 |
| Titanium Large | 44.69 | 4.62 | 46.31 | 61.88 | 51.31 | 65.00 |
| Marine Corps Medium | 33.10 | 2.84 | 34.69 | 53.83 | 44.31 | 59.35 |
| Marine Corps Large | 38.50 | 2.20 | 39.81 | 57.25 | 49.63 | 64.50 |
| Marine Corps Extra Large | 49.00 | 2.00 | 50.50 | 64.75 | 55.50 | 67.00 |

TABLE 16A

Measurement Seated Hip Circumference (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 35.00 | 0.62 | 37.50 | 38.42 | 39.67 | 40.33 |
| Titanium Medium | 40.33 | 2.57 | 42.31 | 44.27 | 43.02 | 45.23 |
| Titanium Large | 48.69 | 3.32 | 49.19 | 51.44 | 50.75 | 52.56 |
| Marine Corps Medium | 38.85 | 3.06 | 41.15 | 42.77 | 43.35 | 43.94 |
| Marine Corps Large | 44.06 | 2.43 | 44.63 | 47.19 | 48.19 | 52.88 |
| Marine Corps Extra Large | 51.25 | 2.75 | 51.75 | 53.75 | 52.75 | 53.25 |

TABLE 17A

Measurement Seated Waist Front (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 13.75 | 0.71 | | | | |
| Titanium Medium | 14.56 | 1.30 | | | | |
| Titanium Large | 15.25 | 0.44 | | | | |
| Marine Corps Medium | 14.38 | 0.94 | | | | |
| Marine Corps Large | 14.75 | 0.44 | | | | |
| Marine Corps Extra Large | 15.50 | 0.50 | | | | |

TABLE 18A

Measurement Seated Sternal Notch to Chin (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 3.86 | 0.19 | | | | |
| Titanium Medium | 3.71 | 0.61 | | | | |
| Titanium Large | 3.11 | 0.37 | | | | |
| Marine Corps Medium | 3.87 | 0.48 | | | | |
| Marine Corps Large | 3.02 | 0.49 | | | | |
| Marine Corps Extra Large | 3.09 | 0.41 | | | | |

TABLE 19A

Measurement Seated Shoulder Width (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 16.61 | 0.53 | 17.64 | 17.58 | 17.17 | 17.80 |
| Titanium Medium | 17.98 | 1.00 | 18.35 | 18.56 | 18.70 | 18.89 |
| Titanium Large | 20.10 | 0.84 | 20.29 | 20.61 | 21.21 | 21.43 |
| Marine Corps Medium | 17.67 | 1.16 | 18.09 | 18.26 | 18.50 | 18.70 |
| Marine Corps Large | 18.80 | 1.13 | 18.98 | 19.54 | 19.73 | 20.01 |
| Marine Corps Extra Large | 20.55 | 0.75 | 20.77 | 21.16 | 20.96 | 20.81 |

## TABLE 20A

Measurement Seated Chest Width (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 10.83 | 0.39 | 10.83 | 10.83 | 12.72 | 13.07 |
| Titanium Medium | 12.25 | 0.52 | 12.32 | 12.40 | 14.60 | 14.63 |
| Titanium Large | 13.98 | 0.74 | 14.11 | 14.22 | 17.03 | 16.67 |
| Marine Corps Medium | 11.94 | 0.81 | 12.02 | 12.03 | 14.65 | 14.70 |
| Marine Corps Large | 12.72 | 0.68 | 12.70 | 12.95 | 16.15 | 16.28 |
| Marine Corps Extra Large | 14.69 | 0.12 | 14.78 | 14.98 | 17.74 | 17.83 |

## TABLE 21A

Measurement Seated Stomach Width (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 8.46 | 0.20 | 8.70 | 15.96 | 13.25 | 18.03 |
| Titanium Medium | 10.52 | 0.79 | 10.87 | 16.69 | 14.37 | 18.48 |
| Titanium Large | 13.22 | 1.81 | 13.84 | 19.85 | 26.61 | 19.85 |
| Marine Corps Medium | 9.93 | 1.07 | 10.37 | 16.41 | 14.37 | 18.75 |
| Marine Corps Large | 11.29 | 0.89 | 11.57 | 17.88 | 16.15 | 19.45 |
| Marine Corps Extra Large | 14.81 | 0.87 | 15.18 | 21.36 | 17.58 | 21.06 |

TABLE 22A

Measurement Standing Shoulder Width (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 16.38 | 0.56 | 16.82 | 17.11 | 17.03 | 17.86 |
| Titanium Medium | 17.96 | 0.83 | 18.19 | 18.27 | 18.64 | 18.80 |
| Titanium Large | 19.94 | 0.80 | 20.20 | 20.28 | 20.73 | 20.94 |
| Marine Corps Medium | 17.60 | 1.07 | 17.91 | 18.02 | 18.43 | 18.78 |
| Marine Corps Large | 18.77 | 1.09 | 18.98 | 19.17 | 19.79 | 19.96 |
| Marine Corps Extra Large | 20.28 | 0.47 | 20.41 | 20.39 | 21.12 | 20.35 |

TABLE 23A

Measurement Seated Hip Width (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 11.82 | 0.30 | 12.56 | 12.48 | 12.48 | 12.68 |
| Titanium Medium | 13.49 | 0.86 | 13.89 | 14.06 | 14.10 | 14.23 |
| Titanium Large | 15.52 | 1.28 | 15.96 | 16.37 | 16.16 | 16.78 |
| Marine Corps Medium | 12.90 | 1.32 | 13.47 | 13.60 | 13.62 | 13.81 |
| Marine Corps Large | 14.22 | 0.52 | 14.56 | 15.15 | 14.75 | 14.88 |
| Marine Corps Extra Large | 16.36 | 1.32 | 16.89 | 17.17 | 16.99 | 18.54 |

TABLE 24A

Measurement Standing Hip Width (Inches)

| Vest Size Grouping | Nude | | Fatigues | | Fatigues and Vest | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | w/o LBE | w/LBE | w/o LBE | w/LBE |
| Titanium Small | 11.88 | 0.18 | 11.90 | 12.14 | 11.96 | 12.19 |
| Titanium Medium | 13.01 | 0.80 | 13.32 | 13.49 | 13.32 | 13.46 |
| Titanium Large | 14.95 | 0.94 | 15.15 | 15.31 | 15.13 | 15.29 |
| Marine Corps Medium | 12.71 | 0.88 | 12.95 | 13.13 | 12.92 | 12.99 |
| Marine Corps Large | 13.78 | 0.74 | 14.1[illegible] | 14.35 | 14.18 | 14.18 |
| Marine Corps Extra Large | 15.57 | 0.85 | 15.47 | 15.75 | 15.67 | 15.91 |